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Natural Resources

Honourable Tim Olive
Minister

D. J. Graham
Deputy Minister

Halifax, Nova Scotia
2003

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Cover photo

High-purity gold in a bedding-parallel quartz vein from Broad River, Queens County. Note how the gold crystals form as leaflets outlining individual quartz grain boundaries. Trace amounts of copper are also present. Sample collected by Lyndon Jensen and photographed by P. K. Smith in 1994. Width of the photo is 1.5 cm.

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Evaporite Karst at the Horton Group - Windsor Group Contact, South-central Cape Breton Island[1]

R. C. Boehner

Introduction

The Mississippian basement contact between the Horton Group and the basal Windsor Group has been one of the most explored and prospective exploration targets for carbonate-hosted base metal, silver, celestite and barite deposits in Nova Scotia. Past producers have included the Walton Barite-Pb-Zn-Ag mine, the Gays River Zn-Pb mine, and the Loch Lomond-Enon celestite mine (Fig. 1). Concordant and discordant mineralization are associated with the contact, both with and without associated fault/fracture systems. The Horton - Windsor and basement contact is a favourable zone due to: (1) the basal Windsor carbonate (e.g. Macumber or Gays River Formation) is a chemically and physically receptive host that lies concordantly but disconformably on top of; (2) coarse- and fine-grained siliciclastics of the Horton Group (or unconformablly on crystalline basement) that served as hydrogeological conduits for mineralizing fluids (and the source of metals), and; (3) the basal anhydrite- and evaporite-dominated Windsor Group overlying the basal carbonate serves as a hydrogeological seal or barrier (aquiclude) to confine and focus fluid flow at the Horton - Windsor contact.

In some areas, such as Rear Black River (Dundee), the Horton Group thins and pinches out on pre-Carboniferous basement and the basal Windsor carbonate (carbonate buildup facies) is deposited directly on basement. More extreme onlap and overstep of Windsor Group strata occur in the Loch Lomond area of southeastern Cape Breton Island where middle and upper Windsor Group strata progressively onlap basement rocks (Boehner and Prime, 1993). Post-depositional tectonics and evaporite karst processes have preferentially affected the Horton - Windsor contact zone. Underground and surface mining operations at Walton, Gays River, and to a lesser extent Loch Lomond, encountered unstable ground conditions as well as large volumes of karst and fracture system controlled groundwater to mine depths exceeding 300 m. The geological features that were favourable to host these mineral deposits, both sealing evaporites and host carbonates, were also conducive to later structural disturbance and subsequent preferential karst development in the near-surface environment. This karst development is integral to the origin of economic high-grade gypsum deposits in south-central Cape Breton Island (e.g. Big Brook, Sugar Camp, Little Narrows, etc.). It also may be important in the development of the late Paleozoic basin petroleum system.

Horton Group - Windsor Group Contact

The outcrop and near-surface geology of the Windsor Group, and especially the Horton - Windsor contact (Fig. 2), is complex due both to a long history (multiple episodes) of structural disruption by faulting and folding as well as evaporite karstification (Paleozoic, Mesozoic and Cenozoic). The lowermost Windsor Group (Major Cycle 1), comprising the basal anhydrite and basal carbonate (Macumber Formation), together with the underlying Horton Group and/or basement rocks, behaved as a structurally competent and relatively immobile structural unit during the tectonic events that deformed the Carboniferous basins (Boehner, 1992; Giles and Lynch, 1994). This contrasts with the highly deformed and mobile (incompetent) strata of the overlying, salt-dominated, middle and upper parts of the Windsor Group. The contact near the top of the basal

[1]Funded by Natural Resources Canada and the Nova Scotia Department of Natural Resources under the Targeted Geoscience Initiative project: Geological Mapping for Mineral Development in South-central Cape Breton Island

Boehner, R. C. 2003: *in* Mineral Resources Branch, Report of Activities 2002; Nova Scotia Department of Natural Resources, Report 2003-1, p. 1-7

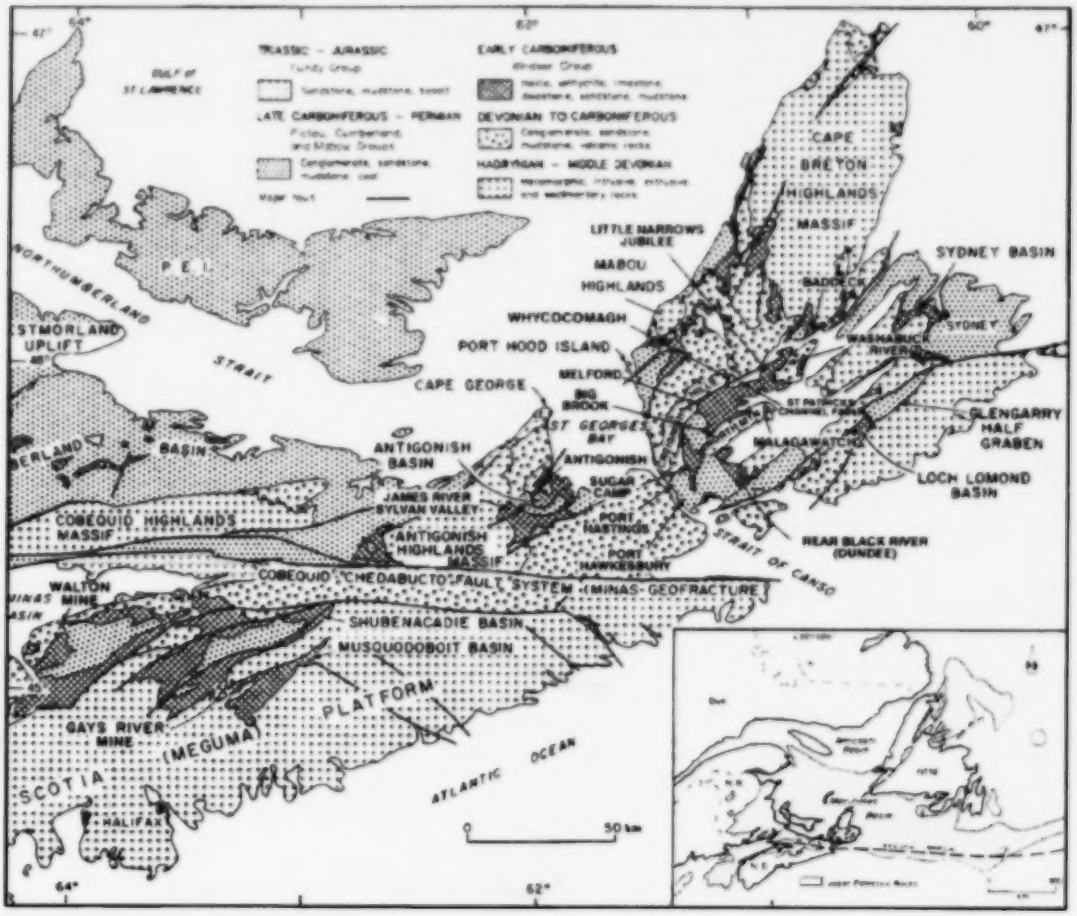


Figure 1. General geology and location map, south-central Cape Breton Island.

anhydrite is often the location of the regionally extensive Ainslie Detachment (Giles and Lynch, 1994), which has developed in the highly ductile, salt-dominated strata above the relatively immobile and competent basal anhydrite.

Strata at the base of the Windsor Group in south-central Cape Breton Island display either faulted or intact depositional conjtacts with older rocks. There are long linear contacts of moderately dipping concordant strata (dips of less than 35 degrees with 10 to 20 degrees typical). The base of the Windsor Group is in normal sedimentary contact (relatively undisturbed) with varying thicknesses of the underlying Horton Group. Examples based on available drilling and geological mapping (Kelley, 1967; Lynch and Brisson, 1996) in south-central Cape Breton Island are described as follows. The northwestern border of North Mountain between Big Brook and River Denys is inferred to have a relatively undisturbed section of the basal Windsor Group; however, the extent is not well confirmed by drill core or availble outcrop. The Washabuck block near Little Narrows and the Sugar Camp block near Port Hawkesbury are relatively well defined in drill core and outcrop. Similar, relatively intact but more steeply dipping and structurally disrupted sections occur along parts of the southern border of the Creignish Hills near Port Hastings and the Strait of Canso, as well as the Glendale-Melford area near Whycocomagh. Much of the southeastern border of

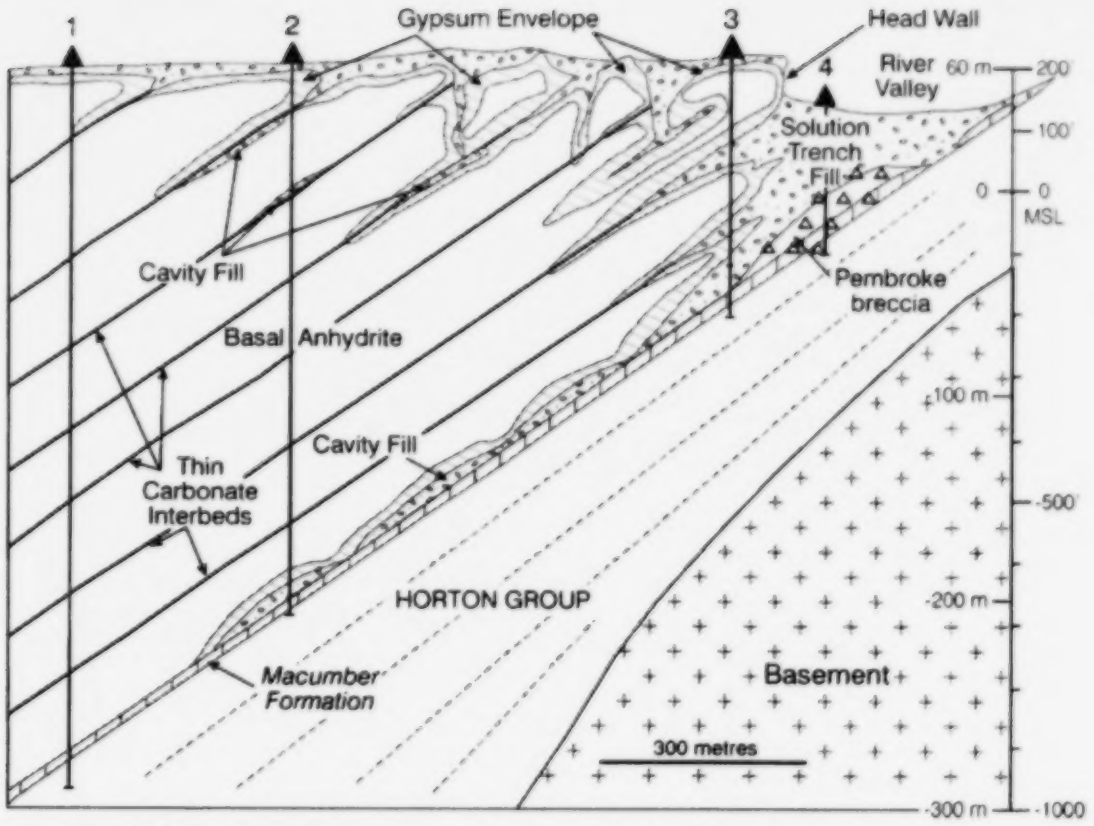


Figure 2. Diagrammatic geological cross-section illustrating karst geology at the Horton Group-Windsor Group contact, south-central Cape Breton Island.

the Creignish Hills, however, is disrupted extensively by faults, including the St. Patricks Channel fault. This is a major northeasterly trending fault (zone) that juxtaposes the middle to upper Windsor Group and possibly Mabou Group with basement and/or Horton Group rocks.

The concordant sedimentary contact between the Windsor Group and underlying Horton Group and/or basement rocks is reasonably well documented in outcrop and drill core. Adams (1991) and Boehner and Giles (1993) described and illustrated the basic concordant stratigraphic contacts associated with the base of the Windsor Group. Where the Horton - Windsor contact strata occur in an undisturbed and moderately to gently dipping succession, there is virtually ubiquitous development of an evaporite solution trench of varied scale and composition. Depending upon the extent of infill and depth of burial, the surface expression may be a well developed linear karst valley landform with extensive sinkholes, gypsum outcrop and modern river drainage (e.g. Washabuck River) or there may little or only very subtle elevation, landform or modern drainage expression at all (e.g. Sugar Camp). The complex age and history of this contact solution trench environment was described by Boehner and Giles (1993). The infill material is heterogeneous, including locally derived (*in situ*) or transported material, and may be lithified or unconsolidated. The unconsolidated material is typically not recovered or only partially recovered in the diamond-drilling process. Locally developed, lithified carbonate breccias of complex age and origin (karst/residual accumulation, solution collapse, tectonic, synsedimentary, etc.) are referred to as Pembroke breccia. The age of

development, based upon the age of the infilling material, ranges from latest Carboniferous, through Cretaceous to Quaternary and Recent.

Morphology of the solution trench is controlled mainly by the down-dip dissolution of relatively soluble anhydrite and gypsum of the thick (300 m+) basal anhydrite. Dissolution occurs preferentially at the contact with the relatively insoluble basal carbonate immediately overlying siliciclastics of the Horton Group, along the boundaries of thin carbonate interbeds with the basal anhydrite, and as discordant fracture zones. The contrasting physical and chemical character of the strata across the basal carbonate/basal anhydrite contact provide a favourable zone for fracturing, faulting, groundwater penetration and circulation. This zone of enhanced primary and secondary porosity and permeability is necessary to develop stratabound evaporite karst systems of varying scales and depths.

The parent anhydrite strata may be hydrated to gypsum as well as dissolved by groundwater. Areas of basal anhydrite with deep hydration may result in economic gypsum deposits with characteristic high grade and whiteness/brightness. Relatively insoluble carbonate that occurs as thin interbeds or inclusions in the anhydrite may be in part dissolved or accumulate in the bottom of karst cavities as residual debris (e.g. lithified depris such as the Pembroke breccia). The basal anhydrite may be 10 to 15% carbonate as thin interbeds, nodules and inclusions, with 20% or more near the basal contact with the Macumber Formation. External sediment may have been washed or foundered down into the cavity system and remained as accumulated infill material (generally unconsolidated) that can be dated by paleontological methods (e.g. Late Carboniferous, Early Cretaceous).

The surface zone of the evaporite karst may range from a width of a few metres to 300 metres and extend along strike for kilometres. Examples include the Washabuck River-Plaster Ponds area near Jubilee and Little Narrows, and the James River-Sylvan Valley area near Antigonish (Boehner and Giles, 1993). The downdip extent of karst development in the basal Windsor Group, based upon limited drilling data, indicates that cavity development (or gypsum as a contact-oriented hydration precursor) rarely occurs below a vertical depth of 300 m. The trench geometry is basically a downdip tapering wedge, bounded at its base by the upper surface plane of the basal carbonate (e.g. Macumber Formation). The upper contact is more irregular and discordant to varying degrees. It is a low-angle curvilinear truncation of the overlying anhydrite strata at their updip extremity.

The basic form of the trench at the surface, where maturely developed, may have a headwall face of gypsum and anhydrite (tens of metres high) at the updip face of the basal anhydrite (hanging wall). This headwall area may contain isolated vertical sinkholes and ponds, and probably represents the complex expansion and interconnection of deep sinkholes developed along the strike trend of the linear contact. Complex cavities, both as discordant and stratabound fissures, may occur in the headwall area of the basal anhydrite. Concordant cavity zones may be associated with thin carbonate interbeds as downdip, horizontal to near-horizontal cavities. Variations of the solution trench karst geometry occur at the Jubilee Zn/Pb deposit where a domal uplift of the Horton Group is defined by a sub-circular ring zone (moat) of partially exposed evaporite karst. In addition, there is an associated discordant karst along a northwest-trending faulted zone (Jubilee Fault) that hosts base metals in the Macumber Formation (basal carbonate) and carbonate breccias. All of these have varying degrees of interconnection and hydraulic connectivity, including open subterranean watercourses connected with surface drainage.

Karst development processes were not confined to the base of the Windsor Group, and extended to varying degrees and depths in all of its evaporitic sections. The connection of the origin of gypsum deposits to evaporite-salt karst and solution-generated karst was outlined by Boehner *et al.* (2002).

Basal Windsor Group - Horton Group Drillholes

The subsurface nature of solution trench features

are documented mainly in mineral exploration drill holes. Example drillholes and source references illustrating the trench geology in south-central Cape Breton Island are described in four categories (diagramatically represented as a composite model in Fig. 2). These represent the extremities from unaltered basal anhydrite to near-surface solution trench sections where the basal anhydrite is entirely absent due to dissolution/weathering. Depending upon depth and development history, the cavities may be open, partially filled, or completely filled with a variety of lithified and unconsolidated surficial material ranging from mud and sand to gravel and boulders.

Type 1 drillholes (Unaffected Sections) are located downdip from significant groundwater penetration. They are characterized by thick, relatively undisturbed and stratigraphically complete sections through the basal anhydrite. These have an intact contact with the underlying basal carbonate (Macumber Formation) which rests concordantly on Horton Group siliciclastics. The depth to the base of the Windsor Group in these drillholes typically exceeds 250 m to 300 m. There is no significant hydration of the basal anhydrite at the contact with the Macumber Formation. There typically is a very thin hydration zone (a few metres) on the upper surface of the basal anhydrite at the contact with the overlying unconsolidated surficial deposits. Representative drillholes include: SJL97-1, SJL97-3 (Jubilee Joint Venture, 1998), JLN-1, JLN-3 near Jubilee/Little Narrows (Westminer, 1993), CB9 and CIB2 near Malagawatch (Chevron Standard Ltd., 1978), SCL-88-11 and SCL-12 near Sugar Camp (Westminer Canada Limited, 1993) and the Bestwall deep hole (NSDNR Record # 4957) near Big Brook.

Type 2 drillholes (Deep Karst Cavity Sections) intersect the deepest extension of karst/hydration development located updip from the unaltered basal anhydrite sections. These are characterized by thick, relatively unaltered sections of the basal anhydrite with gypsum hydration and small karst stratabound cavities. The cavities (filled to open) are developed at the contact with the underlying basal carbonate (Macumber Formation), which rests concordantly on Horton Group siliciclastics. The depth to the cavity zone in these drillholes rarely exceeds 250 m to 300 m, and typically occurs at depths of 250 m or less. There is minor hydration of the basal anhydrite at the cavity contact with the Macumber Formation. Representative drillholes include: PH-1-91 (247-276 m) in the Sugar Camp area (Scotia Prime Minerals Incorporated, 1992), IR-3-74 (275 m+) near the superb karst of the Plaster Ponds in the Jubilee/Iona Rear area (Texas Gulf, 1978).

Type 3 drillholes (Shallow Trench Cavity Sections), which intersect the core of the karst development zone, occur updip from Type 2 and extend downdip from the headwall of the solution trench near the outcrop limits of the basal anhydrite. These drilled sections are typically less than 150 m deep and are characterized by thick, variably hydrated and karsted sections through the basal anhydrite. There is locally extensive gypsum hydration and karst cavity development including: stratabound and discordant fissures, sinkholes-dolines, valley sinks, pinnacles and haystack hills along the hanging wall of the basal anhydrite and at the contact with the underlying basal carbonate. The cavity zone depth in these drillholes rarely exceeds 40 m and typically occurs at depths less than 150 m. Hydration of the basal anhydrite to gypsum occurs in an envelope that extends around the overhanging headwall of the basal anhydrite. The stratigraphy of these drillholes appears to be unusual; they typically have the following section downhole: overburden, gypsum, anhydrite, gypsum, trench cavity fill, basal carbonate, Horton Group. In fact, there may be multiple cavities and gypsum zones in the basal anhydrite section above the main solution trench zone. Representative drillholes include: S1 (107-114 m) near Sugar Camp (Rio Tinto Canadian Exploration Ltd., 1974), 141-3 (118-158 m) near Washabuck Bridge/ Little Narrows (St. Joseph Explorations, Ltd., 1974a) and 139-2 (93-158 m) near River Denys (St. Joseph Explorations, Ltd., 1974b).

Type 4 drillholes (Solution Trench Sections) occur updip from Type 3, and are essentially entirely within the solution trench updip and beyond the outcrop limits (headwall) of the basal anhydrite. These drilled sections are typically less than 100 m deep, but may reach 150 m. They are characterized by the absence of *in situ* anhydrite or

gypsum of the basal anhydrite, with only unconsolidated surficial karst infill deposits directly overlying the basal carbonate. The cavity zone in the Type 4 drillholes progressively becomes enlarged at the outcrop limits to widths that may exceed 300 m. These wide (hundreds of metres) and elongate (kilometres) landform features, often topographic lows, are the location for major parallel surface drainage in the region (e.g. Washabuck River, and Big Brook/River Denys). Representative drillholes include: JBL97-1 (0-78 m) near Upper Washabuck/Little Narrows (Kaoclay Resources Inc., 1997), 139-1 (0-93 m) near River Denys (St. Joseph Explorations, Ltd., 1974b) and RD-2 (0-73 m) near Melford/Upper River Denys (Texas Gulf, 1977).

Conclusions

The Horton Group - Windsor Group and basement contact is a favourable and prospective zone for mineralization because the basal Windsor carbonate is a chemically and physically receptive host that lies on top of siliciclastics of the Horton Group or crystalline basement, which serve as hydrogeological sources for metals and conduits for mineralizing fluids. The impermeable anhydrite overlying basal carbonate served as a seal to confine and focus fluid flow at the Horton - Windsor contact, and comparisons may be made to source, reservoir and seal rocks in a petroleum system.

This contact is geologically complicated due to post-depositional and syn- to post-mineralization tectonics and evaporite karst processes that have preferentially affected the Horton-Windsor contact zone. Evaporite karst development occurred in multiple episodes controlled by regional and local tectonics and erosional events in the late Paleozoic, Mesozoic, and Cenozoic eras.

The subsurface nature of solution trench karst features at the base of the Windsor Group is documented mainly in mineral exploration drilling and to a lesser extent in mine/quarry workings. The diagrammatic cross-section in Figure 2 and the example drillholes, illustrate the interpreted trench geology in south-central Cape Breton Island in four categories. Type 1 drillholes are unaffected sections. Depth to the base of the Windsor Group in these drillholes typically exceeds 250 m to 300 m. There is no significant hydration of the anhydrite or karst cavity development. Type 2 drillholes include deep karst cavity sections in the deepest extension of karst/hydration development. These have limited gypsum hydration and small karst stratabound cavities at depths rarely exceeding 250 m to 300 m, and typically at depths of 250 m or less. Type 3 drillholes intersect shallow trench cavity sections that define the core of the karst development zone. This occurs immediately downdip from the headwall of the solution trench near the outcrop limits of the basal anhydrite. These drilled sections are typically less than 150 m deep and are characterized by variable and generally extensive hydration and karstification of the basal anhydrite. Type 4 drillholes are essentially entirely within the solution trench updip and beyond the outcrop limits (headwall) of the basal anhydrite. These drilled sections are typically less than 100 m deep and are characterized by the absence of *in situ* anhydrite or gypsum of the basal anhydrite, with only unconsolidated surficial karst infill deposits directly overlying the basal carbonate.

Underground and surface mining operations in the basal Windsor Group at Walton, Gays River, and to a lesser extent Loch Lomond, encountered unstable ground conditions in the hanging wall. Large volumes of karst and fracture system controlled groundwater infiltrated to mine depths exceeding 300 m.

The geological features that were favourable to host these mineral deposits were also conducive to later structural disturbance and subsequent preferential evaporite karst development in the near-surface environment. Karst development and associated groundwater infiltration and hydration of anhydrite is integral to the origin of economic high-grade gypsum deposits in south-central Cape Breton Island (e.g. Big Brook, Sugar Camp, Little Narrows). The karst process history also may be important in the development of the late Paleozoic basin petroleum system.

References

Adams, G. C. 1991: Gypsum and anhydrite resources in Nova Scotia; Nova Scotia Department

of Natural Resources, Economic Geology Series 91-1, 293 p.

Boehner, R. C. 1992: An overview of the role of evaporites in the structural development of Carboniferous basins in Nova Scotia; *in* Mines and Energy Branch, Report of Activities 1991, ed. D. R. MacDonald; Nova Scotia Department of Natural Resources, Mines and Energy Branch, Report 92-1, p. 39-56.

Boehner, R. C., Adams, G. C. and Giles, P. S. 2002: Geology and origin of gypsum in Nova Scotia: the evaporite-salt karst connection; *in* Mineral Resources Branch, Mining Matters for Nova Scotia, 2002, ed. D. R. MacDonald; Nova Scotia Department of Natural Resources, Report ME 2002-2, p. 4.

Boehner, R. C. and Giles, P. S. 1993: Geology of the Antigonish Basin, Nova Scotia; Nova Scotia Department of Natural Resources, Mines and Minerals Branch, Memoir 8, 109 p.

Boehner, R. C. and Prime, G. 1993: Geology of the Loch Lomond Basin and Glengarry Half-graben, Nova Scotia; Nova Scotia Department of Natural Resources, Mines and Minerals Branch, Memoir 9, 68 p.

Chevron Standard Ltd. 1978: Brasdor Prospect M458, 1978 drill program strip logs and location map; Nova Scotia Department of Natural Resources, Assessment Report 11F/15B 07-J-71 (02).

Giles, P. S. and Lynch, G. 1994: Stratigraphic omission across the Ainslie Detachment in east-central Nova Scotia; *in* Current Research 1994-D, Geological Survey of Canada, p. 89-94.

Jubilee Joint Venture 1998: Assessment report on 1998 exploration programs, Mineral Exploration Licences 03130, 2664, 221 and 167, Map Sheet 11K/02B, Dena's Pond, Jubilee, Caines Mountain Areas, Victoria and Inverness Counties, Nova Scotia, Michael Cullen; Nova Scotia Department of Natural Resources, Assessment Report 98-116.

Kaoclay Resources Inc. 1997: A report on the Jubilee/Washabuck Property, Cape Breton, Nova Scotia, 11F/15C and 11K/02B; Nova Scotia Department of Natural Resources, Assessment Report 97-026.

Kelley, D. G. 1967: Baddeck and Whycocomagh map areas with emphasis on Mississippian stratigraphy of central Cape Breton Island, Nova Scotia; Geological Survey of Canada, Memoir 351.

Lynch, G. and Brisson, H. 1996: Bedrock Geology, Whycocomagh 11F/14, Cape Breton Island, Nova Scotia; Geological Survey of Canada, Open File Map 2917, scale 1:50 000.

Rio Tinto Canadian Exploration Ltd. 1974: Lead/zinc, Sugar Camp/West Bay, Inverness County, Nova Scotia; Quebec Uranium Mining Corp.; Nova Scotia Department of Mines and Energy, Assessment Report 11F/11C, 11D 27-J-58(03).

St. Joseph Explorations, Ltd. 1974a: An assessment report on the Washabuck area, Victoria County; Nova Scotia Department of Mines and Energy, Assessment Report 11K/02B 27-Q-35(01)

St. Joseph Explorations, Ltd. 1974b: An assessment report on the River Denys area, Victoria County; Nova Scotia Department of Mines and Energy, Assessment Report 11F/14A 27-J-53(01)

Scotia Prime Minerals Incorporated, 1992: An assessment report on work performed on Exploration Licenses, West Bay, Cape Breton, Nova Scotia, Canada; Nova Scotia Department of Natural Resources, Assessment Report AR 91-111.

Texas Gulf 1977: Assessment Report, River Denys, Inverness County; Nova Scotia Department of Natural Resources, Assessment Report 11F/14C 07-J-21(02).

Texas Gulf 1978: Assessment Report, Iona Rear, Victoria County; Nova Scotia Department of Natural Resources, Assessment Report 11F/15 AR78-001.

Westminer Canada Limited 1993: Summary on 1992/93 exploration program on Exploration License 00221, Jubilee, Victoria County, Nova Scotia; Nova Scotia Department of Natural Resources, Assessment Report 11F/15 AR93-030.

Karst Geology in the Salt-bearing Windsor Group Evaporites and Controls on the Origin of Gypsum Deposits in South-central Cape Breton Island, Nova Scotia[1]

R. C. Boehner, G. C. Adams[2] and P. S. Giles[3]

Introduction

All economically significant occurrences of gypsum and anhydrite found in Nova Scotia are hosted by the Mississippian (Early Carboniferous) Windsor Group (Fig. 1). The Windsor Group consists of interstratified marine evaporites, marine carbonates and nonmarine siliciclastic sedimentary rocks (Figs. 2 and 3) which were deposited in a large complex intracontinental basin. The Windsor Group is typically underlain by the Horton Group, a thick sequence of continental siliciclastic sedimentary rocks. The Horton Group and locally the Windsor Group strata were deposited in the early stages of the basin system over older

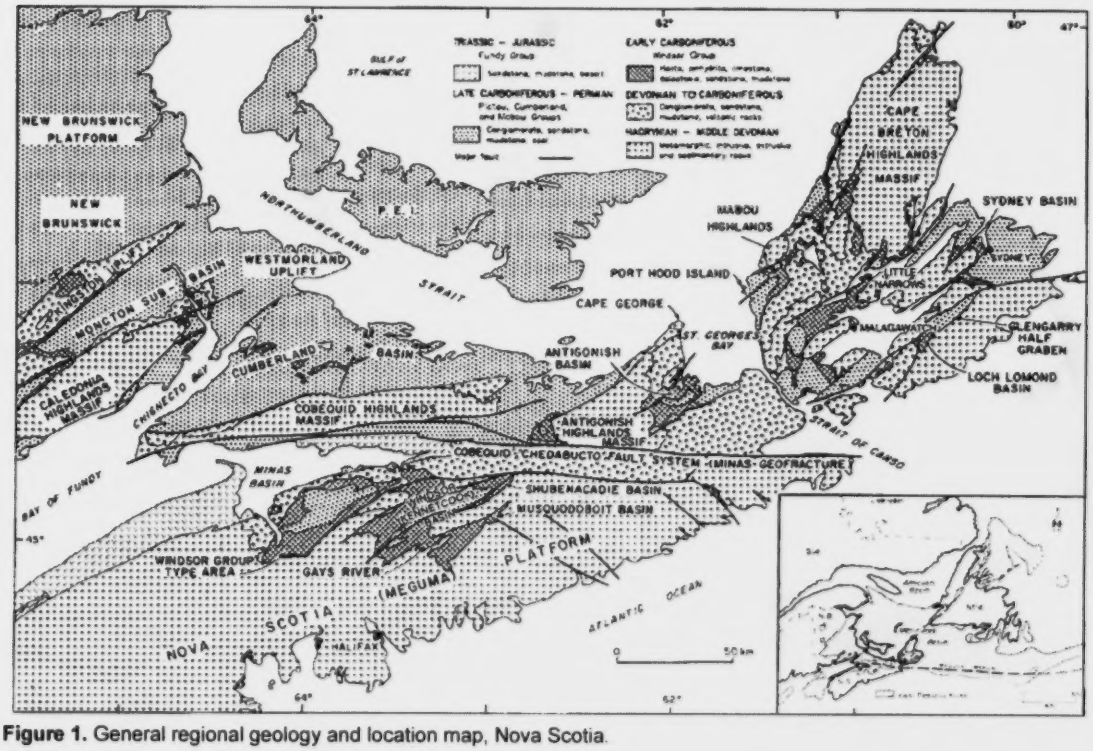


Figure 1. General regional geology and location map, Nova Scotia.

[1]Funded by Natural Resources Canada and the Nova Scotia Department of Natural Resources under the Targeted Geoscience Initiative project: Geological Mapping for Mineral Development in South-central Cape Breton Island
[2]Nova Scotia Treasury and Policy Board, PO Box 1617, Halifax, NS B3J 2Y3
[3]Natural Resources Canada, Geological Survey of Canada, PO Box 1006, Dartmouth, NS B2Y 4A2

Boehner, R. C., Adams, G. C. and Giles, P. S. 2003: *in* Mineral Resources Branch, Report of Activities 2002; Nova Scotia Department of Natural Resources, Report 2003-1, p. 9-24.

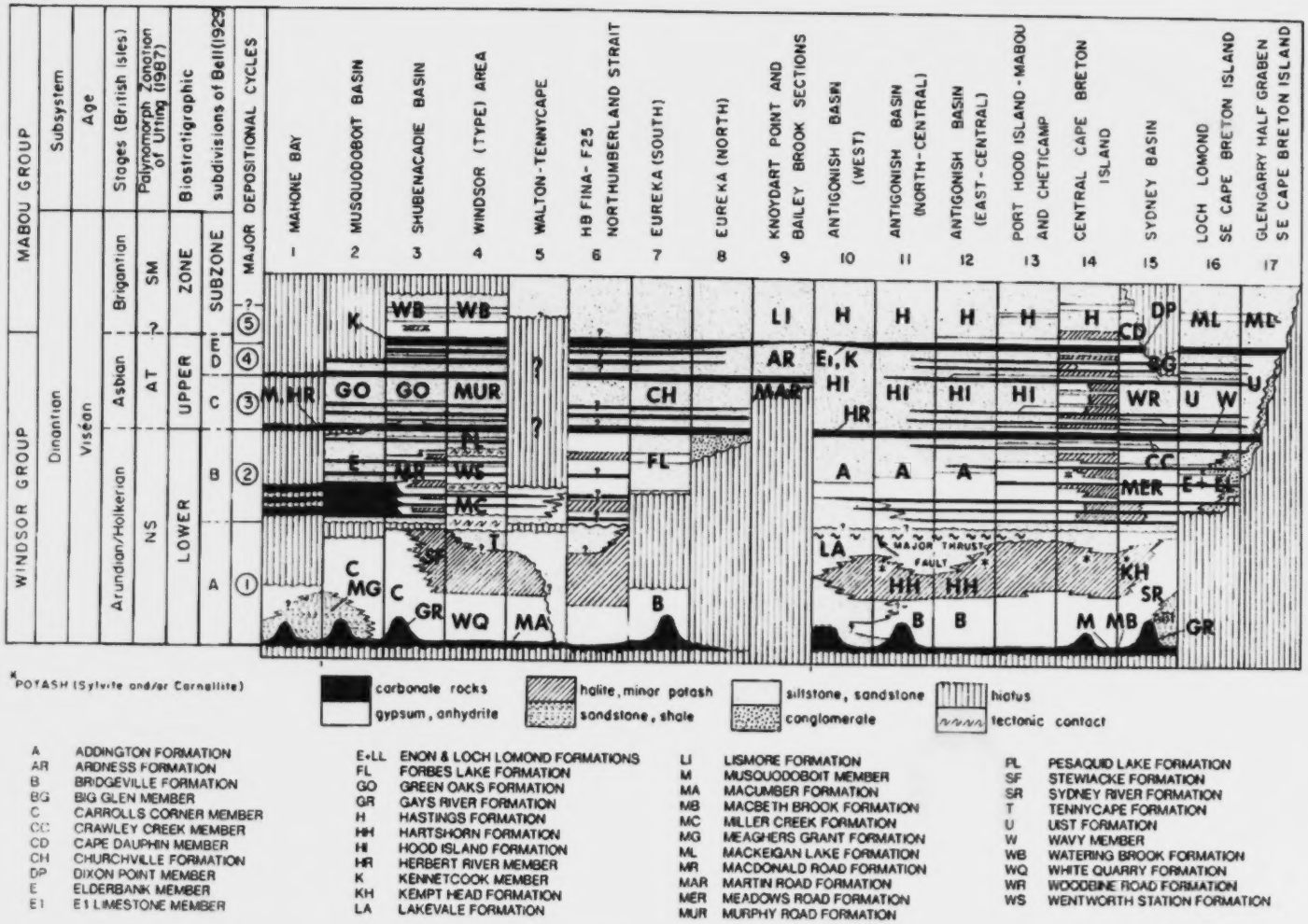


Figure 2. Windsor Group lithostratigraphy and major cycle correlations in Nova Scotia.

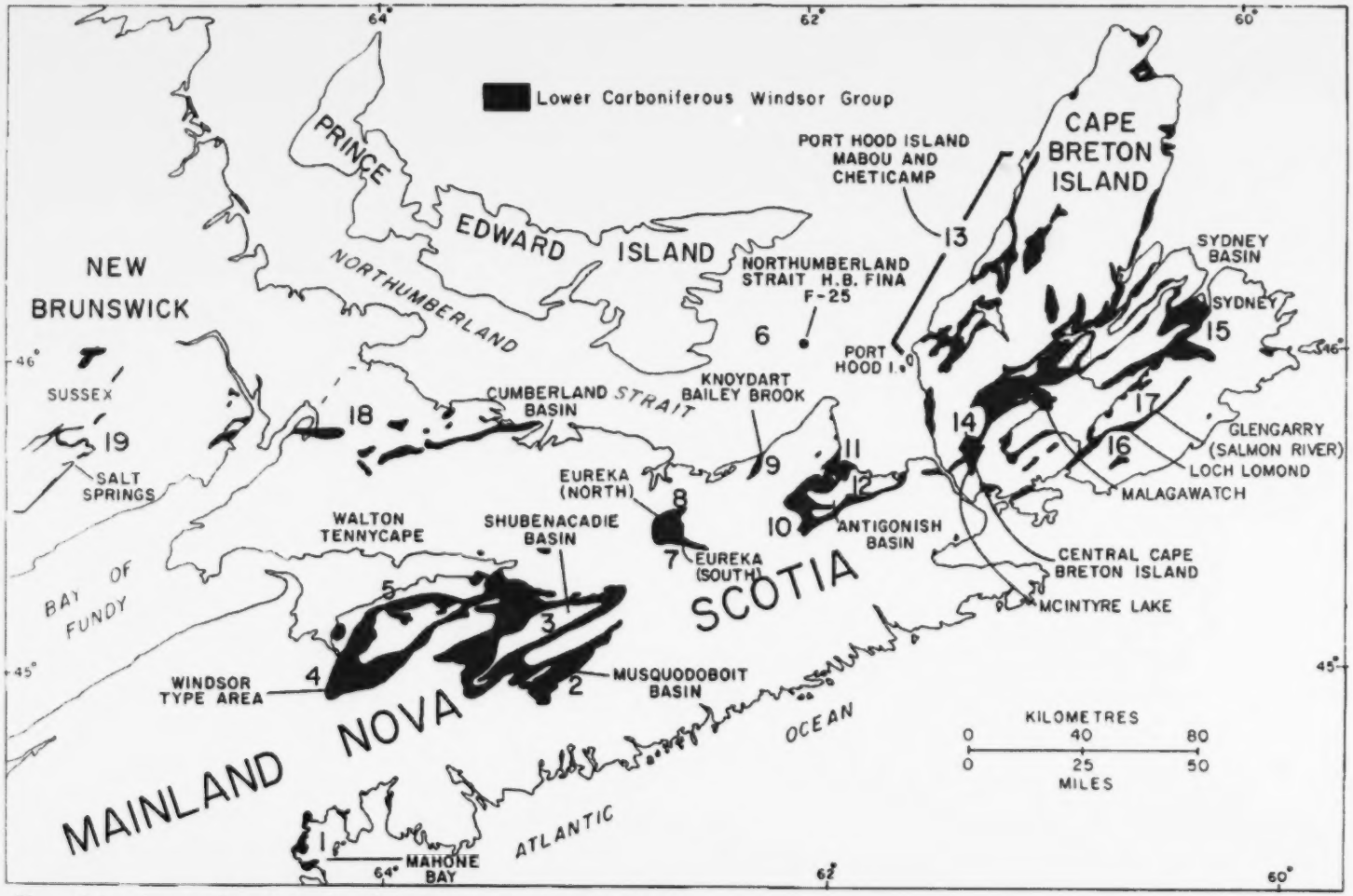


Figure 3. Location map for major cycle and stratigraphic sections in Nova Scotia.

deformed metamorphic and igneous rocks. Fine-grained continental siliciclastics of the Mabou (Canso) Group conformably overlie the Windsor Group, although locally, younger Carboniferous strata of the Cumberland (Riversdale) and Pictou groups may overlie the Windsor Group with an unconformity or fault contact.

Prior to Adams (1991), little information was published on the geology of gypsum and anhydrite resources of the province (Bell, 1929; Goodman, 1952; Schenk, 1969 and 1984; Lewis and Holleman, 1983). Substantial advances have been made in the past 20 years in understanding the geology, stratigraphy and structure of the Windsor Group rocks that host gypsum deposits in the province. Much of this increased knowledge has been made possible by new subsurface data generated by numerous drilling and seismic exploration projects for base metal, salt, potash and hydrocarbon deposits. Significant additions to the previous work by Adams (1991) on gypsum deposits include: (1) recognition of the close stratigraphic, structural and tectonic relationship between the geology of salt in the deep subsurface and gypsum in the near surface; (2) recognition of a more extensive distribution and thickness of anhydrite (parent mineral of gypsum in Nova Scotia) in the thick evaporitic sections of the Upper Windsor Group (Major Cycles 3 to 5 of Giles, 1981); and (3) increased understanding of the extent and role of complex, multiple-generation karst development in the origin of gypsum deposits in the evaporite-dominated Windsor Group (Boehner and Giles, 1993; Boehner and Prime, 1993).

In many ways, the Windsor Group gypsum deposits are the near-surface karst-altered derivatives of deeper basin (down-dip) anhydrite and salt deposits. This is especially applicable in heterogeneous and deformed gypsum deposits (types 3, 4 and 5 described by Adams, 1991). There has been a long-recognized mineral alteration/ replacement facies change from gypsum down into anhydrite. It is now evident that this mineralogical change is also linked with further change down-dip to salt facies. The dissolution process involving circulating groundwater not only hydrated the anhydrite to gypsum, but also removed salt associated with anhydrite to depths exceeding 400 m.

An important factor in the formation of major gypsum deposits is decollement tectonics. This occurs at both a local and regional scale (e.g. Ainslie Detachment, Lynch and Giles, 1995; Lynch *et al.*, 1998) and produces some of the complex recumbent and isoclinal folding characteristic of many areas in the salt- and anhydrite-dominated Windsor Group. Salt content in the stratigraphic section is a major factor in facilitating the development of this structural style (salt is highly ductile). The repetition of strata, especially the more competent anhydrite, by folding and faulting may be an important contributor to enhancing the hydration process as well as the economic thickness of gypsum deposits.

The stratigraphic, structural, tectonic and evaporite karst dissolution connections to the origin of gypsum deposits outlined above are the result of recent work in south-central Cape Breton Island funded by the federal-provincial Targeted Geoscience Initiative. This includes the detailed investigations by Giles (2003) of the complex geology of salt and potash deposits associated with the Windsor Group in central and southern Cape Breton Island. Because the geology of gypsum deposits is intimately linked to local stratigraphy and structure, readers are directed to descriptions and illustrations of basin scale geology as well as associated salt and potash deposits (e.g. Boehner, 1984, 1986, and 1992, Giles, 2003, Giles and Lynch, 1994, Lynch and Giles, 1995). The following section is an overview of the stratigraphy and lithologic composition of Windsor Group major and minor cycles.

Major Cycles

Bell (1929) systematically described the stratigraphy and paleontology of the Windsor Group in the type area near Windsor, Hants County. Workers from the late 1960s to the present introduced a detailed lithostratigraphic nomenclature of formations and members based on local structural basins (Giles, 1981). A complex nomenclature of numerous formations and

members (many are correlative units) has consequently developed (Figs. 2 and 3).

Giles (1981) used the lithostratigraphy as a basis for describing the Windsor Group as a system of five major transgressive-regressive depositional cycles (Fig. 2). Generally these major cycles are complex and comprise multiple minor deposition cycles. These minor or minicycles, with thicknesses of metres to tens of metres, typically include, in ascending order: marine carbonates, anhydrite, halite, and red/green mudrock. Although the five major cycles have been defined primarily on the basis of lithostratigraphy, they coincide closely with biostratigraphy defined by Bell (1929). Major Cycles 1 and 2 of Giles (1981) correlate with the Lower Windsor A and B subzones of Bell (1929), and Major Cycles 3 to 5 correlate with the C, D and E subzones of the Upper Windsor. The major cycle nomenclature has been applied to the Windsor Group throughout the province and serves as a simplified framework for correlation and comparison of facies variations (Figs. 2, 3 and 4). The uppermost of these cycles, Major Cycle 5, extends transitionally into the overlying Hastings Formation of the Mabou (Canso) Group.

Gypsum and anhydrite occur in all five major cycles in the Windsor Group (Figs. 2 and 4), and locally evaporite deposits (anhydrite and salt) extend into the basal part of the Mabou (Canso) Group. Economically significant sections of gypsum and anhydrite (Lewis and Holleman, 1983) are generally restricted to the lower Windsor Group, Major Cycles 1 and 2 (Giles, 1981; Boehner, 1984 and 1986; Adams, 1991). Major Cycle 1 is up to 400 m thick and comprises 40-90% $CaSO_4$, Major Cycle 2 is 150 to 530 m thick and is up to 55% $CaSO_4$, and Major Cycles 3 to 5 are 150 to 470 m thick and typically contain <20% $CaSO_4$. The evaporite component of these cycles may be increased substantially (Fig. 6), and locally dominated by the highly water-soluble mineral halite (NaCl) with local potash (KCl). For example, Major Cycle 1 may be up to 75% halite, and in saline evaporitic sections in central Cape Breton Island, Major Cycle 2 may comprise up to 55% halite, and Major Cycles 3 to 5 up to 35% halite. The composition of an average Major Cycle 1 section in the central Cape Breton Island area (Fig. 5) is 7% carbonate, 11% siliciclastic, 42% anhydrite and 40% salt. Major Cycle 2 is 530 m thick and comprises 7% carbonate, 16%

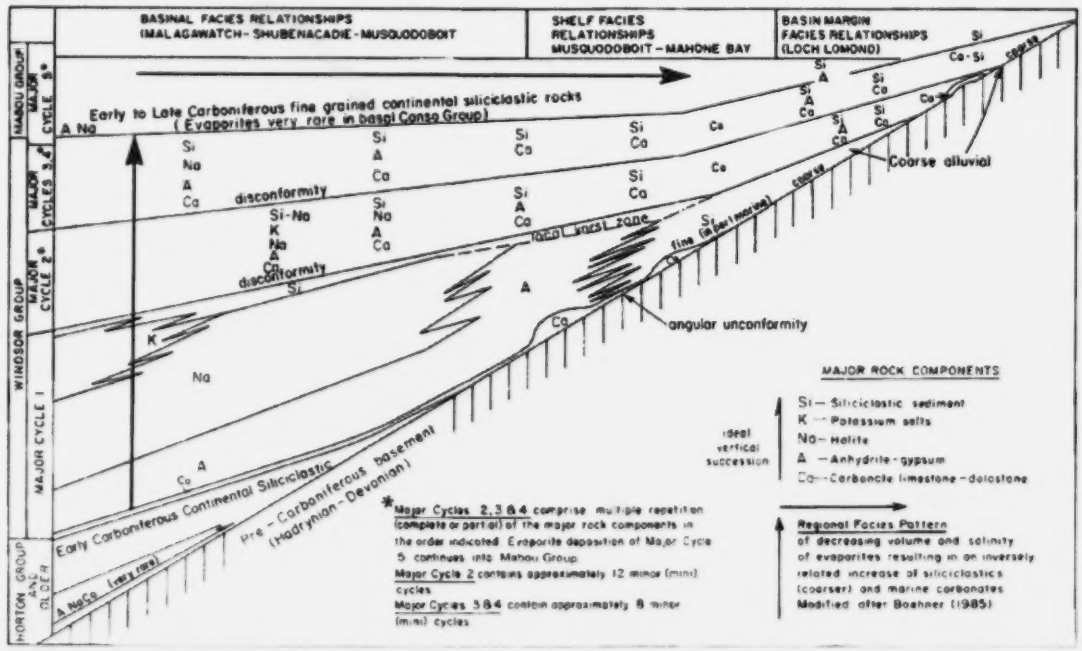

BASINAL FACIES RELATIONSHIPS (MALAGAWATCH - SHUBENACADIE - MUSQUODOBOIT
SHELF FACIES RELATIONSHIPS MUSQUODOBOIT - MAHONE BAY
BASIN MARGIN FACIES RELATIONSHIPS (LOCH LOMOND)
Early to Late Carboniferous fine grained continental siliciclastic rocks (Evaporites very rare in basal Canso Group)
disconformity
angular unconformity
Coarse alluvial
MAJOR ROCK COMPONENTS
Si — Siliciclastic sediment
K — Potassium salts
Na — Halite
A — Anhydrite - gypsum
Ca — Carbonate limestone - dolostone
ideal vertical succession
Regional Facies Pattern
of decreasing volume and salinity of evaporites resulting in an inversely related increase of siliciclastics (coarser) and marine carbonates
Modified after Boehner (1985)
Early Carboniferous Continental Siliciclastic
Pre - Carboniferous basement (Hadrynian - Devonian)
MABOU GROUP
WINDSOR GROUP
MAJOR CYCLE 1
MAJOR CYCLE 2
MAJOR CYCLES 3,4
MAJOR CYCLE 5
HORTON GROUP AND OLDER

Figure 4. Schematic representation of Windsor Group facies relationships in Nova Scotia.

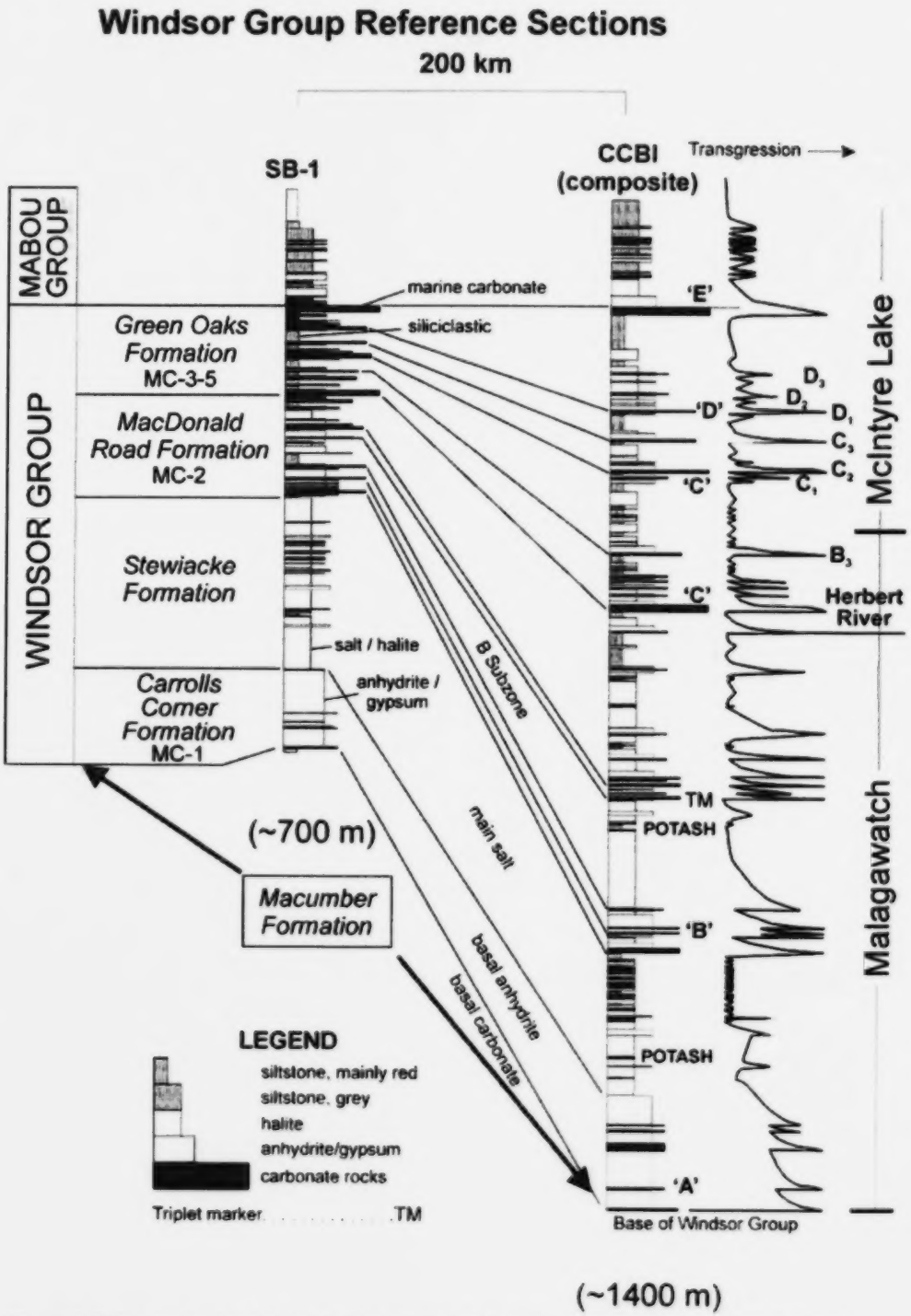


Figure 5. Reference section correlation, Shubenacadie Basin (SB1) and central Cape Breton Island composite section (CCB1 Malagawatch and McIntyre Lake).

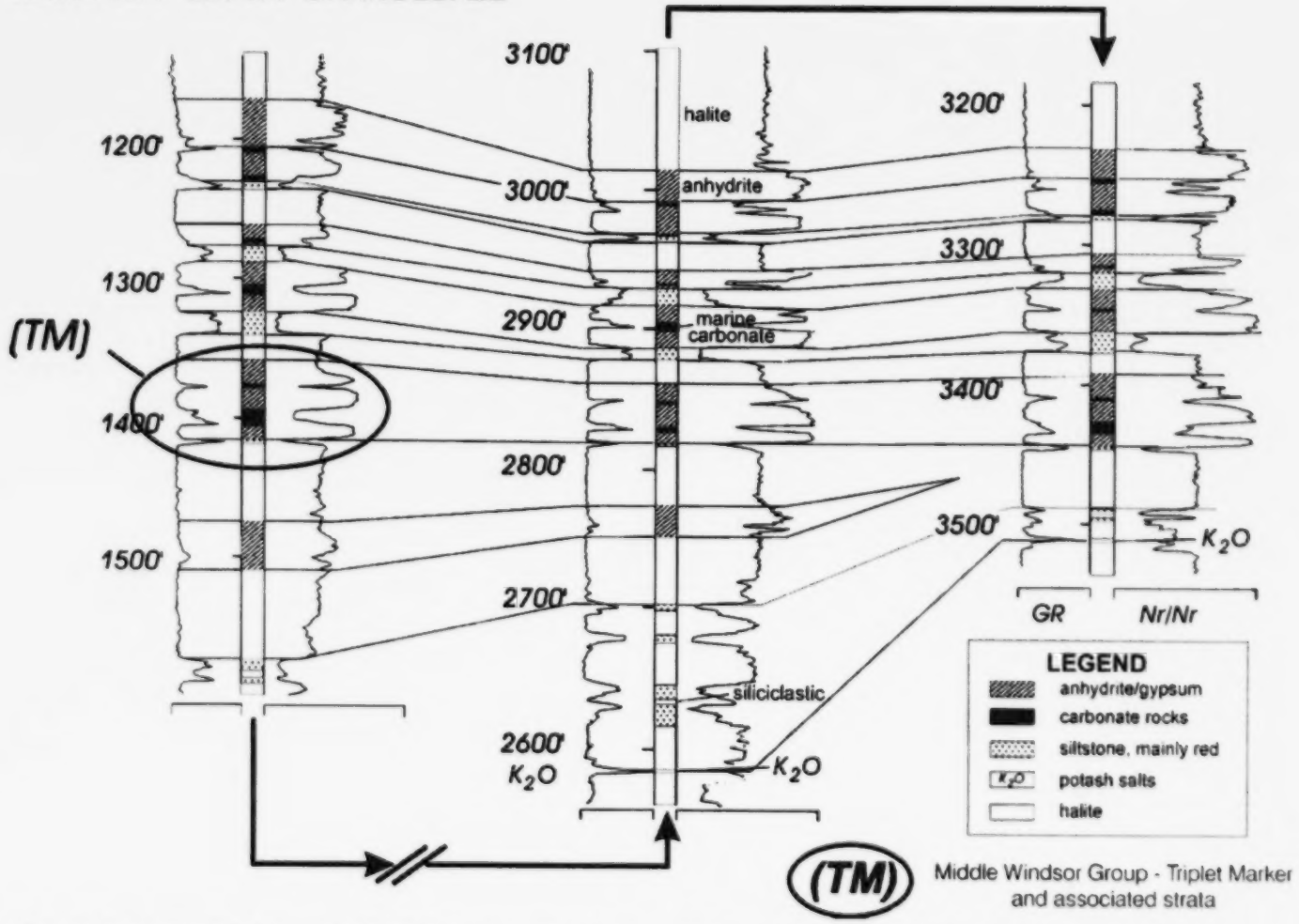


Figure 6. Major Cycle 2, B Subzone 'Triplet Marker' and associated strata correlation in complex fold repeated section, Noranda drillhole 225-5A, Orangedale Deposit near Malagawatch.

siliciclastic, 22% anhydrite and 55% salt. Major Cycles 3 to 5 comprise 11% carbonate, 36% siliciclastic, 17% anhydrite and 36% salt. The overall Windsor Group composition of Major Cycles 1 to 5 (1400 m thick) is 8% carbonate, 21% siliciclastic, 26% anhydrite and 45% salt.

The highly water-soluble halite is removed by dissolution in the near-surface environment and rarely occurs at depths shallower than 300-400 m. The relative proportion of the anhydrite, including both thick strata and thin interbeds common in the stratified salt sections, may increase when salt is removed. For example, if salt is removed from the saline evaporitic sections (e.g. Major Cycles 3 to 5 in central Cape Breton Island; Figs. 5, 6 and 7), the anhydrite component increases to approximately 27%. This increased thickness favours more economically attractive gypsum zones.

After dissolution of the salt, the overall composition of an average Major Cycle 1 section (240 m thick), calculated for the evaporitic sections above depths of 300-400 m, in central Cape Breton Island area is 11% carbonate, 18% siliciclastic and 71% anhydrite. This includes the variably abundant anhydrite interbeds in the main salt section. Portions of anhydrite are hydrated to gypsum to a maximum depth of 400 m (hydration decreases rapidly with depth) but the greatest concentration of gypsum occurs within the upper 100 m. Because Major Cycle 1 (basal anhydrite) is massive and relatively competent, fracture permeability has limited development and typically there is a thin hydration zone. Gypsum associated with the basal anhydrite, however, tends to high grade and white.

Major Cycle 2 in central Cape Breton Island, with the salt removed, is typically 240 m thick and comprises 15% carbonate, 35% siliciclastics and 50% anhydrite. A greater portion of the anhydrite is hydrated to gypsum to a maximum depth of 400 m due to permeabilty associated with the carbonate and siliciclastic interbeds and fracturing associated with folding and faulting. Major Cycles 3 to 5 in central Cape Breton Island, after removal of the salt, would be 300 m thick and comprise 17% carbonate, 56% siliciclastics and 27% anhydrite. Similar to Major Cycle 2, Major Cycles 3-5 typically have thicker hydration zones. The overall Windsor Group composition of Major Cycles 1 to 5 with the salt removed (780 m thick) is 15% carbonate, 38% siliciclastic and 47% anhydrite.

The relative proportion of anhydrite, and the vertical and lateral facies distribution in each stratigraphic unit or cycle, is thus a factor governing gypsum potential. Structural repetition by recumbent and isoclinal folding and faulting is preferentially associated with salt-bearing sections due to the relative incompetence and mobility of salt rocks. The resulting stacking of anhydrite zones in the deformed sections may be another major factor in enhancing gypsum potential. Many of the current gypsum mines in the province operate in this stratigraphic and structural environment.

Gypsum Deposit Classification

Adams (1991) described and illustrated five types of gypsum deposits in Nova Scotia (Fig. 8). Two of the types were associated primarily with Major Cycle 1 (A Subzone) and three were associated with Major Cycle 2 (B Subzone). Readers are directed to the detailed descriptions of Adams (1991) for deposit types 1 to 4, as well as the descriptive notes with Figure 8.

Subsequent to Adams (1991) there is a much greater understanding of the distribution of salt and related decollement structures in the down-dip and deeper basin extensions of Adams's (1991) type 5 deposits. Gypsum deposit type 5 is complex and occurs above the basal anhydrite near the base of Major Cycle 2 (B Subzone) as types 3 and 4. The deformation and disruption of the beds is typically so complete that little remains of the original beds that made up the section (Fig. 8). The mechanisms that produced these deposits are still unclear and may include tectonic brecciation related to faulting, either thrusting or decollement (Boehner, 1992), and/or collapse brecciation after the dissolution of halite. There is a close spatial and genetic relationship with salt dissolution zones and related residual accumulation of anhydrite/gypsum in the near-surface outcrop areas of the tectonically disturbed main salt at the contact between Major Cycles 1 and 2.

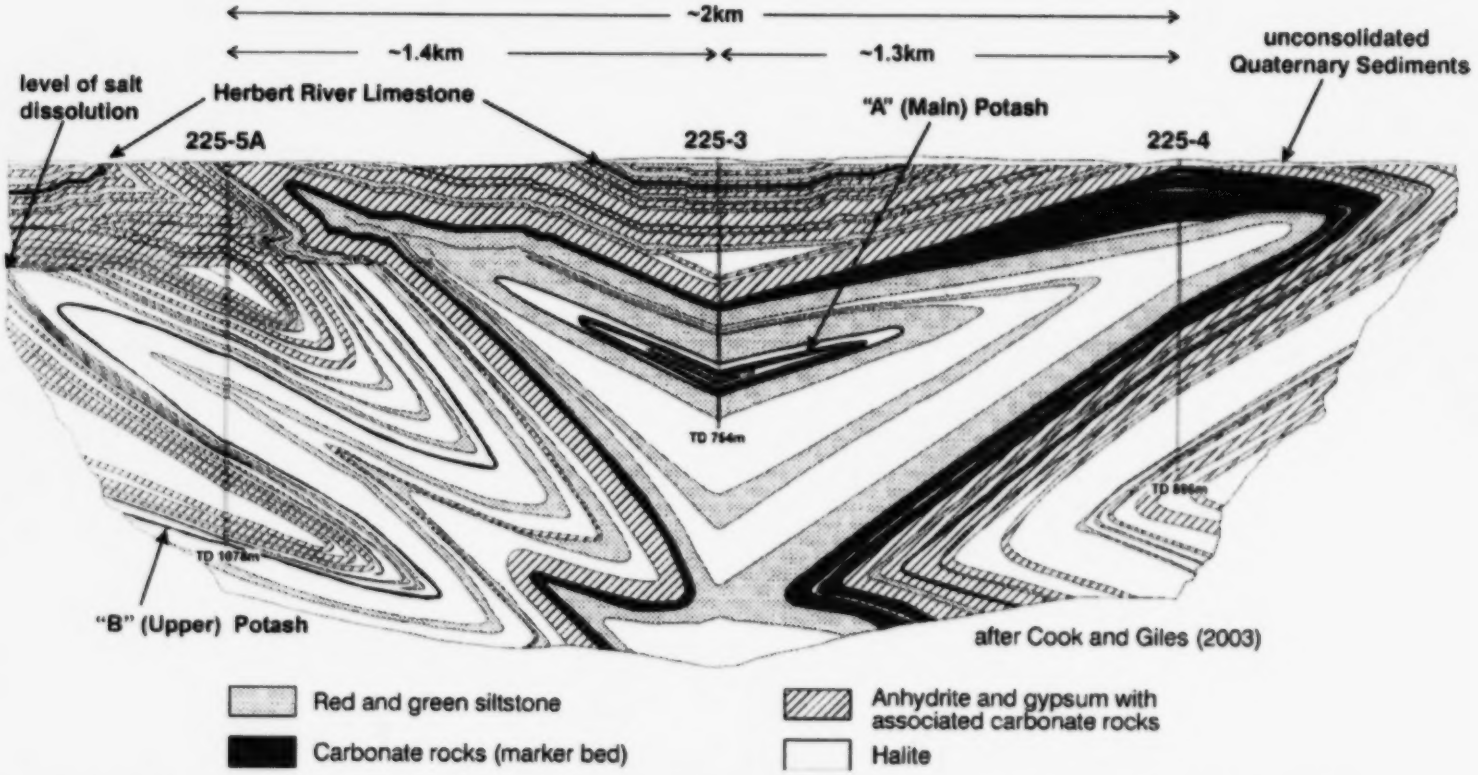


Figure 7. Detailed cross-section through part of the Orangedale salt deposit modified after Cook and Giles, 2003. Note the interpreted continuity of the stratigraphy (deflated, foundered, brecciated with anhydrite variably hydrated to gypsum) in the near-surface evaporite karst zone. Here the salt has been removed by groundwater dissolution to depths exceeding 400 m.

The geology and origin of type 5 gypsum deposits are interpreted to be closely related to the tectonics and dissolution of salt associated with the regionally extensive main salt of Major Cycle 1. Although dominated by salt, there is a significant component of anhydrite interbeds that enhances the gypsum content of this stratigraphic/structural zone. Anhydrite content of the main salt section of Major Cycle 1 in saline basinal sections is approximately 8-10% or more, and may exceed 20% in transitional sections with the basal anhydrite. Therefore, with the removal of salt, they would attain a cumulative thickness of 30 to 60 m. In addition, anhydrite from the upper part of the basal anhydrite that is locally disrupted by faulting is also a contributor to the gypsum zone in type 5 deposits.

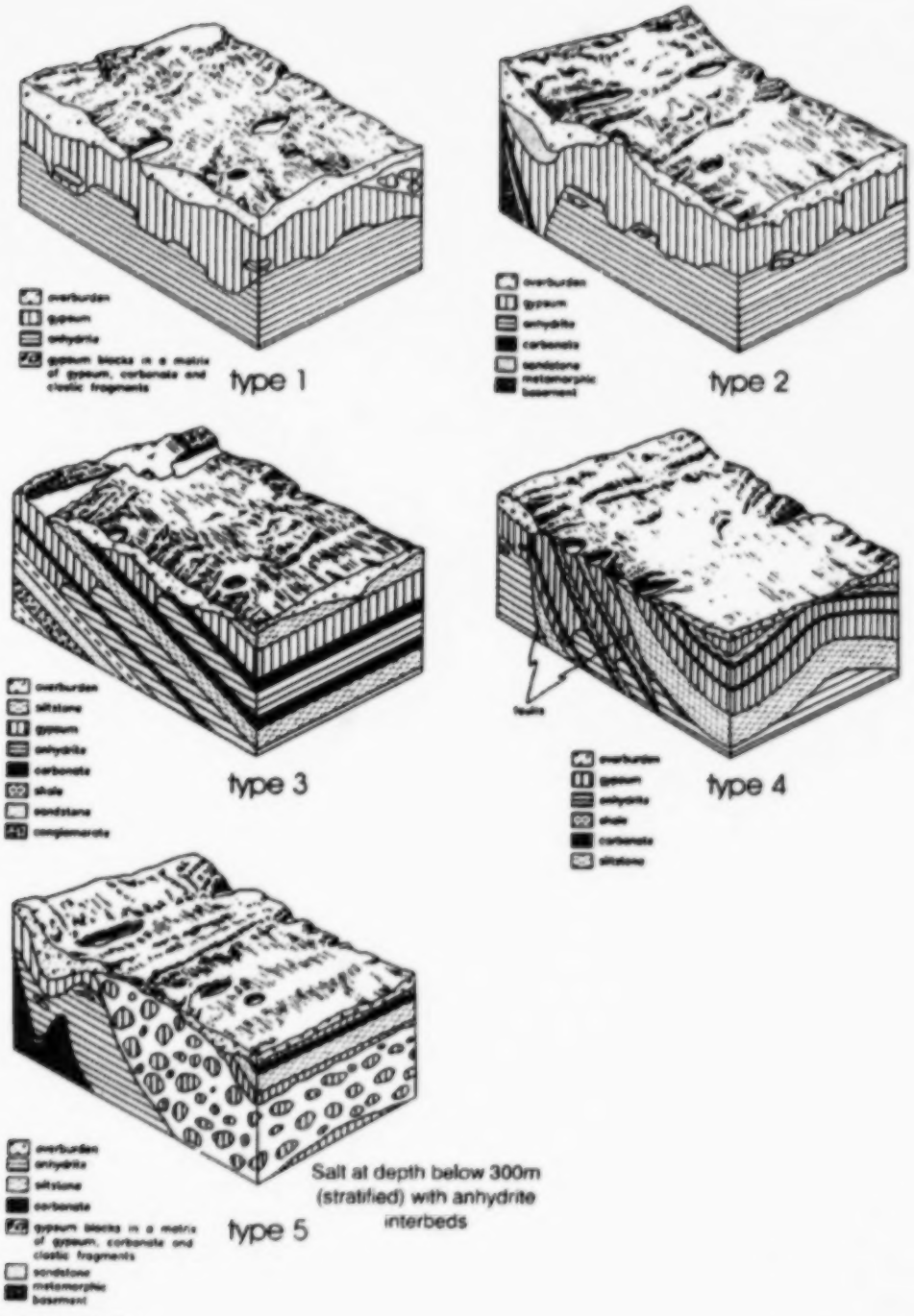
Geological Controls on Economic Gypsum Deposits

Lewis and Holleman (1983) described the stratigraphic location and identified deposit genesis factors associated with major gypsum and anhydrite production sites in Nova Scotia. They placed all active mines within the A and B Subzones of the Lower Windsor Group (Major Cycles 1 and 2 of Giles, 1981). Several factors were identified as important in the localization of these gypsum deposits including: (1) a large primary component of $CaSO_4$, (2) the influence of structural disturbance concentrated at this stratigraphic level (e.g. structural decollement, collapse, etc.), and (3) enhanced permeability due to structure and paleodrainage (geomorphology). These remain as the main factors; however, additional factors and variations of them (e.g. the salt connection) are presented here.

The significant relationship of tectonics, local structure, and anhydrite content of the stratigraphy to economic gypsum deposits is well documented in the Little Narrows area, where the near-surface extension of Major Cycle 2 strata is mined by Little Narrows Gypsum Company in a complexly folded section without significant salt (Wilson and Sharpe, 1994). The down-dip extensions of these units were intersected in deep diamond-drill core hole R1W, drilled by Chevron at MacIvers (McIvor) Point (total depth 1185 m/3890 ft.) approximately 3.5 km north of the gypsum quarries (Boehner and Giles, 2003). The R1W drillhole intersected a recumbently folded Major Cycle 2 and 3 section to a depth of approximately 1000 m. This interval was dominated by salt below a depth of 400 m. The major folds recognized in the drill core on the basis of multiple repeated stratigraphy (especially in Major Cycle 2), have limbs with dips of 30 to 60 degrees and fold limb intersection intervals of 50 to 150 m. The contact with the underlying Major Cycle 1 is inferred to be a decollement in the disrupted main salt section above the top of the basal anhydrite at a depth of approximately 1170 m. The decollement zone has a calculated dip of approximately 15 degrees to the north. This is based on an interpolated and extrapolated cross-section (southeast to northwest) of the St. Patricks Channel salt deposit (Boehner and Giles, 2003) constructed from Washabuck, through the Little Narrows Gypsum Quarry, to MacIvers (McIvor) Point R1W drillhole and St. Patricks Channel.

This disturbed contact is well defined in the Little Narrows gypsum quarries as a distinct structural break above the basal anhydrite. The associated enhanced hydration zone in the anhydrite beds found in the lower part of Major Cycle 2 and the upper part of the basal anhydrite

Figure 8 (facing page). Summary of evaporite deposit classification in Nova Scotia (after Adams, 1991). Deposit type 1 shows shallow surface hydration of massive 'basal anhydrite', with gypsum development limited by permeability (e.g. permeable carbonate interbeds or fracturing). Deposit type 2, a variation of type 1, shows surface hydration and deeper hydration along the contact with the underlying 'basal carbonate' of the Windsor Group and older strata, with gypsum development enhanced by increased permeability (e.g. permeable carbonate/siliciclastic interbeds or fracturing associated with this disrupted contact zone). Deposit type 3 shows surface hydration and deeper hydration enveloping the anhydrite along the contacts with permeable carbonate and siliciclastic strata of the Windsor Group. Deposit type 4, a variation of type 3, shows enhanced hydration enveloping the anhydrite associated with structural deformation and faults creating increased permeability in carbonate/siliciclastic interbeds or fracturing. Deposit type 5 shows massive disruption of the original strata, especially at the contact between the 'basal anhydrite' and the B Subzone (Major Cycle 2) of the Lower Windsor (a local and regional decollement fault zone). Hydration development extends to depths exceeding 100 m, and typically occurs up-dip from variably deformed stratigraphic sections dominated by salt but with significant anhydrite interbeds (e.g. 'main salt' of Major Cycle 1). Note that salt is typically preserved only below depths of 300 to 400 m.



after Adams (1991)

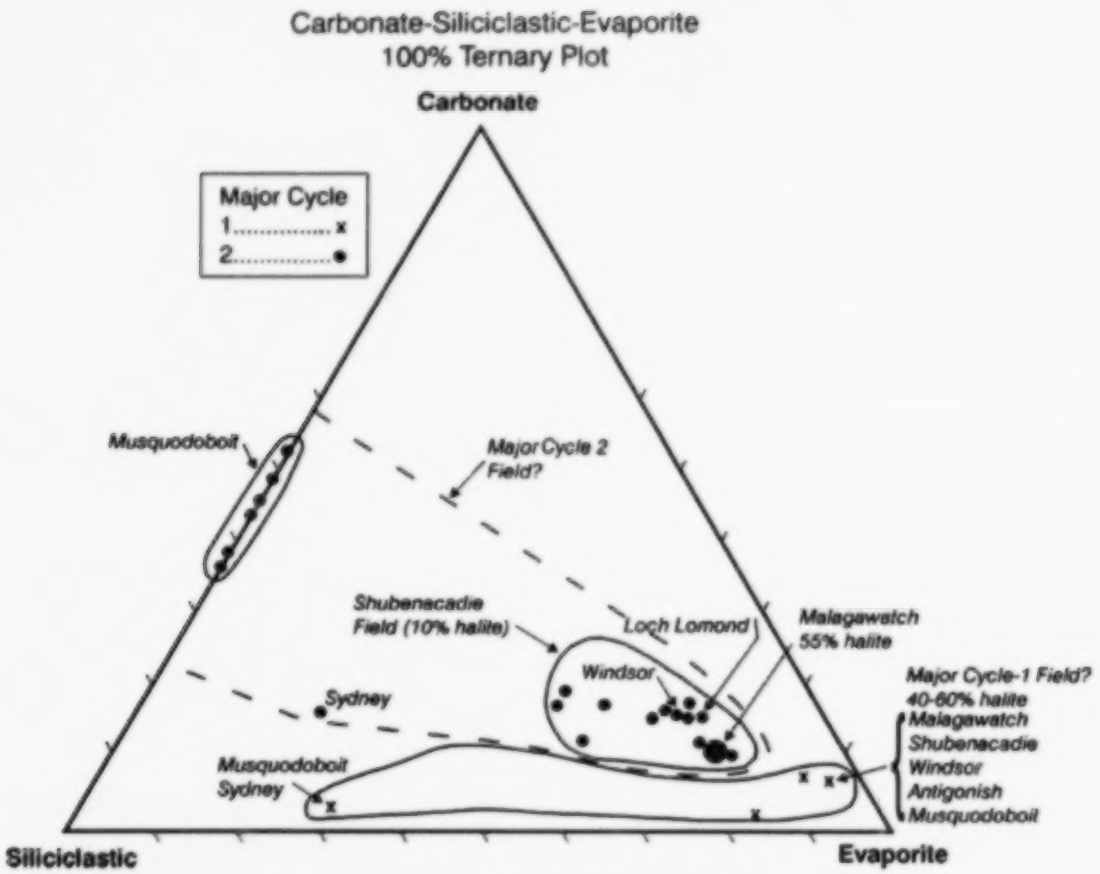


Figure 9. Ternary plot of the lithology of Major Cycle 1 and 2 sections in Nova Scotia.

comprises the main gypsum units mined at Little Narrows (Wilson and Sharpe, 1994). The anhydrite-dominated lower part of Major Cycle 2 and the upper part of the basal anhydrite, separated by an intervening structurally disturbed decollement/dissolution zone, are well known as a prospective environment for economic gypsum deposits throughout the province (Lewis and Holleman, 1983; Adams, 1991).

The middle part of the B subzone (Fig. 6) is also prospective because it also has a high concentration of anhydrite associated with the evaporitic facies of the constituent minor cycles (cf. triplet marker of Giles and Boehner, in prep.). The upper part of Major Cycle 2 typically has more siliciclastics and thus more waste material than the lower units. The Upper Windsor typically contains less anhydrite than the Lower Windsor. Each marine carbonate member is overlain by anhydrite of variable thickness. Some groupings of these minor cycles in evaporitic sections may contain proportions and cumulative thicknesses of anhydrite comparable to Major Cycle 2 (Fig. 9). These become prospective exploration targets where the anhydrite beds are near surface and hydrated to gypsum. Anhydrite is well developed in several of the minor cycles of Major Cycles 3 and 4 (Fig. 10). Similarly, anhydrite may be a substantial component of the uppermost Windsor, Major Cycle 5 in the transition into the overlying Mabou Group.

The cumulative thickness and stratigraphic (depositional) distribution of anhydrite, the parent mineral form of gypsum, is a primary factor in

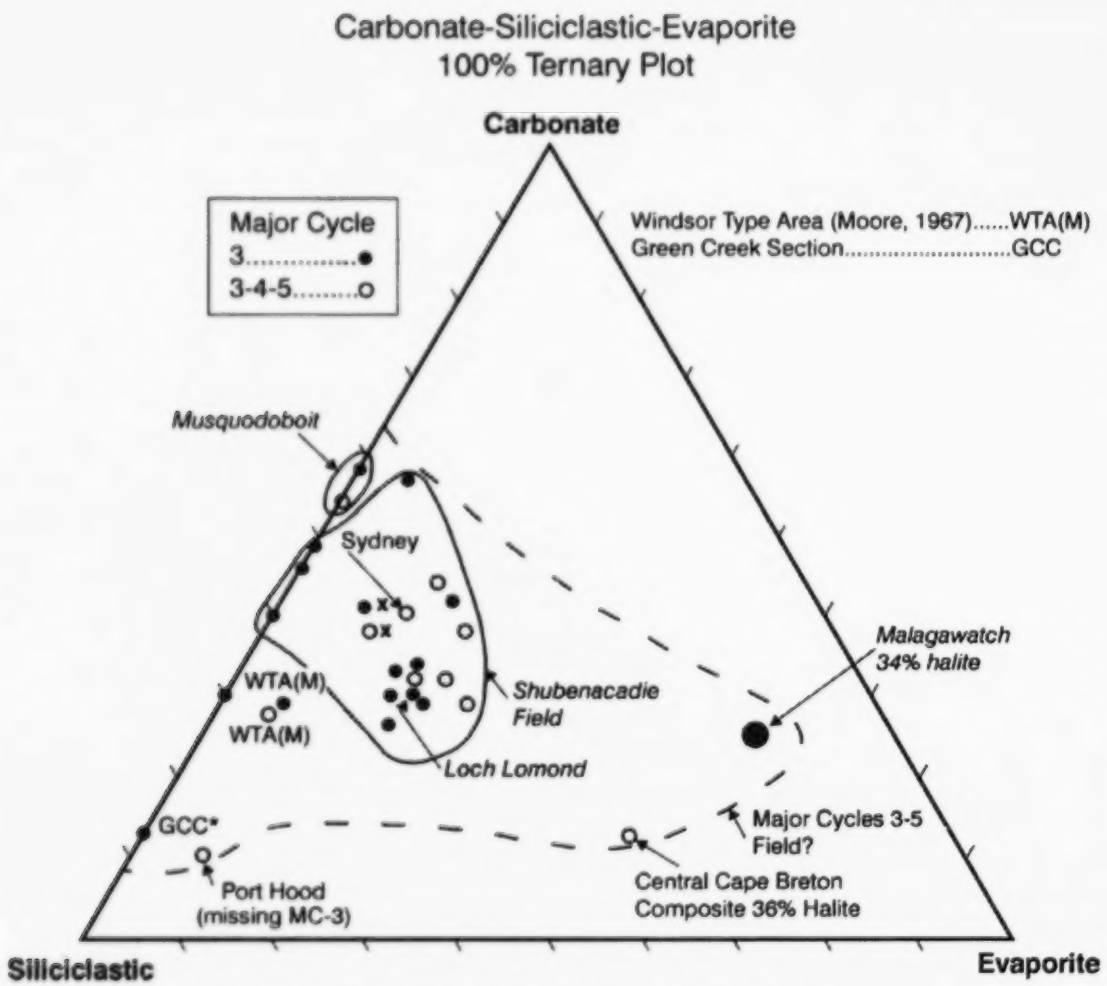


Figure 10. Ternary plot of the lithology of Major Cycle 3, 4 and 5 sections in Nova Scotia.

gypsum deposits. The following is an overview of the stratigraphic distribution of anhydrite in the major cycles of the Windsor Group. The proportion of anhydrite varies considerably, both stratigraphically and laterally, within and between basins in Nova Scotia (Figs. 2, 3 and 4) with major trends described by Giles (1981) and Boehner (1984).

The distribution of anhydrite in the thick saline Windsor Group sections in central Cape Breton provides further insight into prospective gypsum intervals. Visual inspection of the lithology distribution within the Windsor Group central Cape Breton composite section (Giles and Boehner, 2001) indicates the anhydrite is not evenly distributed, especially in Major Cycles 2 to 5 (Fig. 5). Within Major Cycle 2 there are two prominent intervals of concentrated anhydrite strata. The degree of concentration may be further enhanced (thickened) when the halite intervals are removed, as illustrated in the following examples.

One interval occurs prominently at the base of Major Cycle 2. This is a zone comprising approximately: 41.5 m (136 feet) anhydrite, 2.7 m (9 feet) siltstone, and 4.9 m (16 feet) carbonate as aggregate thickness of the carbonate, anhydrite and

siliciclastic strata. These units are tentatively correlated with the main economic gypsum mining zone at Little Narrows comprising three to four minor cycle units described by Wilson and Sharpe (1994). They indicate that up to 75% of the mining section is gypsum, and it sometimes occurs as large (10 m) blocks with green siltstone. Individual gypsum beds are 1.5-20 m thick and average 7.5 m. Salt and anhydrite content increase with depth in the mining zone at Little Narrows (Holleman, 1976).

The second significant anhydrite interval occurs in the middle part of Major Cycle 2 at the stratigraphic level of the 'triplet marker' described by Giles and Boehner (2001). The 'triplet marker', which is a distinctive package of multiple minor cycles of carbonate, anhydrite, salt and siliciclastic strata, contains the significant anhydrite zone (Fig. 6). The 'triplet marker' comprises approximately 47.5 m (156 feet) anhydrite, 2.7 m (9 feet) siltstone, and 15.8 m (52 feet) carbonate. It correlates with the North Salem and Hardwoodlands members interval in the Macdonald Road Formation (Major Cycle 2) in the Shubenacadie Basin (Giles and Boehner, 1979, 1982).

The Major Cycle 2 section in the Windsor Group central Cape Breton composite section contains overall: 7% carbonate, 16% siliciclastic, 22% anhydrite and 55% halite. Consequently, removal of the halite component in the near surface by dissolution processes increases the proportion of anhydrite to approximately 49% and the resulting residual accumulation serves as the parent for subsequent gypsum formation by hydration. The volume of halite and its highly ductile behaviour also facilitates deformation and stacking (repetition) of the anhydrite beds (potential gypsum) by folding and faulting.

Within the Windsor Group central Cape Breton composite section (WGCCBC), the saline evaporite facies of both Major Cycles 3 to 5 and Major Cycle 2 should be considered as prospective sites for gypsum deposits where there are anhydrite-enriched stratigraphic intervals. The Major Cycles 3 to 5 section in WGCCBC section (Fig. 5) contains similar proportions of evaporites as Major Cycle 2 sections that host economic gypsum deposits in other basins in the province. Anhydrite is not evenly distributed and overall the composition is 11% carbonate, 36% siliciclastic, 17% anhydrite and 36% halite. If salt is removed from the saline evaporitic sections of Major Cycles 3 to 5, the anhydrite component increases to approximately 27%. Similar to Major Cycle 2, if the salt component is removed there are three favourable intervals of concentrated anhydrite recognized.

There is a lower interval including several minor cycles constituting part of the C subzone including the C1, C2 and C3 limestones. This zone comprises approximately: 29 m (95 feet) anhydrite, 12 m (39 feet) siltstone, and 11 m (36 feet) carbonate. There is an overlying anhydrite-enriched interval including several minor cycles constituting part of the D subzone, including the D1, D2 and D3 limestones. This zone comprises approximately 20.4 m (67 feet) anhydrite and 3 m (10 feet) carbonate. The third interval of gypsum potential occurs above the E1 Limestone at the top of the Windsor Group in the transition to the overlying Hastings Formation of the Mabou Group. An anhydrite bed 15.8 m (52 feet) thick of potential economic interest occurs as the lowermost of several anhydrites in minor cycles of grey mudrock, anhydrite and halite.

In all three intervals of anhydrite enrichment, structural repetition and salt dissolution may produce enhanced thicknesses of anhydrite. Hydration of anhydrite to gypsum in the near-surface environment may produce economic deposits. The relatively high proportion of halite in the Major Cycles 3 to 5 section (up to 36%), although lower than in the underlying Major Cycle 2, may also be favourable for the development of complex folds. This is in contrast to correlative sections containing little or no salt, which is typical of many other basins in the province. The tectonics and structural disturbance at the lower stratigraphic levels, including the lower part of the B subzone and upper part of the basal anhydrite and the overlying main salt of the A subzone, are inferred to further enhance the development of substantial gypsum deposits (e.g. Little Narrows).

The salt dissolution and structural environment described above is an extension of, or process unification of the five gypsum deposit types identified by Adams (1991). Variations of this structural/dissolution gypsum environment, including local high-angle faults, are associated with the gypsum deposits at Big Brook, Sugar Camp and Melford. It is probably present in a related form at the Alba and Big Hill deposits, although the detailed geology is not well known.

Summary

Understanding the geologically favourable factors for gypsum deposit formation is important in developing an effective exploration and development strategy. Some of the important geological factors have been described previously and the following is a synopsis. The geological factors include:

(1) the primary cumulative thickness and stratigraphic (depositional) distribution of anhydrite (parent form of gypsum) in each of the major cycles,

(2) spatial localization of enhanced anhydrite cumulative thickness related to structural repetition of beds in proximity to major structural and paleotopographic features within and bounding the Windsor Group basins,

(3) enhanced hydration of anhydrite beds resulting from an increase in permeability related to fracture density increases in proximity to major structural and paleotopograhic features,

(4) an increase in the cumulative proportion of anhydrite in each of the major cycles related to salt dissolution in the near-surface environment,

(5) an increase in the mineralogical conversion of anhydrite to gypsum resulting from an increase in permeability in anhydrite related to evaporite karst development (collapse brecciation and fracturing) in the near-surface environment,

(6) geological distribution of the favourable contacts associated with the deposits, for example the base of Major Cycle 1 (Horton/Windsor Group) or Major Cycle 1 and 2 contact, and

(7) geological history to allow the preservation of the hydration areas and zones from erosion.

Cumulatively these are the primary geological factors influencing the location and geological nature of gypsum deposits of economic significance (mineability, size and grade). Although these factors are not uniformly distributed stratigraphically, spatially or temporally, they can be integrated into exploration models and strategies. Non-geological, cultural, environmental and economic factors, including location with respect to transportation, mineability, land availability, use and access, are major (critical) governing factors on the development potential for any given deposit.

References

Adams, G. C. 1991: Gypsum and anhydrite resources in Nova Scotia; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Economic Geology Series 91-1, 293 p.

Bell, W. A. 1929: Horton-Windsor District, Nova Scotia; Geological Survey of Canada, Memoir 155, 268 p.

Boehner, R. C. 1984: Stratigraphy and depositional history of marine evaporites in the Windsor Group, Shubenacadie and Musquodoboit structural basins, Nova Scotia, Canada; Ninth International Carboniferous Congress, 1979; Compte Rendu, v. 3, p. 173-178.

Boehner, R. C. 1986: Salt and Potash Resources in Nova Scotia; Nova Scotia Department of Mines and Energy, Bulletin No. 5, 346 p.

Boehner, R. C. 1992: An overview of the role of evaporites in the structural development of Carboniferous basins in Nova Scotia; *in* Mines and Energy Branch, Report of Activities 1991, ed. D. R. MacDonald; Nova Scotia Department of Natural Resources, Report 92-1, p. 39-56.

Boehner, R. C. and Giles, P. S. 2003: Preliminary report on the St. Patricks Channel salt deposit, Victoria County, Cape Breton Island, Nova Scotia; *in* Mineral Resources Branch, Report of Activities 2003, ed. D. R. MacDonald; Nova Scotia Department of Natural Resources, Report ME 2003-1, p. 25-32.

Boehner, R. C. and Giles, P. S. 1993: Geology of the Antigonish Basin, Antigonish County, Nova Scotia; Nova Scotia Department of Natural Resources, Memoir 8, 109 p.

Boehner, R. C. and Prime, G. 1993: Geology of the Loch Lomond Basin and Glengarry Half-graben, Nova Scotia; Nova Scotia Department of Natural Resources, Mines and Minerals Branch, Memoir 9, 68 p.

Cook, L. and Giles, P. S. 2003: Stratigraphy and structure of the Orangedale Salt Deposit, central Cape Breton Island, Nova Scotia; Geological Survey of Canada Open File 1529, 1 sheet.

Giles, P. S. 2003: Stratigraphy and structure of the Malagawatch Salt Deposit, central Cape Breton Island, Nova Scotia; Geological Survey of Canada Open File 1531, 1 sheet.

Giles, P. S. 1981: Major transgressive and regressive cycles in the middle to late Viséan rocks of Nova Scotia; Nova Scotia Department of Mines and Energy, Paper 81-2, 27 p.

Giles, P. S. and Boehner, R. C. in prep: Windsor Group stratigraphy and structure drill core orientation field trip 2001 guidebook; Nova Scotia Department of Natural Resources, Minerals and Energy Branch, Open File Report.

Giles, P. S. and Boehner, R. C. 1982: Geological map of the Shubenacadie and Musquodoboit basins, central Nova Scotia; Nova Scotia Department of Mines and Energy, Map 82-4, scale 1:50 000.

Giles, P. S. and Boehner, R. C. 1979: The Windsor Group stratigraphy in the Shubenacadie and Musquodoboit basins of central Nova Scotia; Nova Scotia Department of Mines and Energy, Open File Report 410.

Giles, P. S. and Lynch, G. 1994: Stratigraphic omission across the Ainslie Detachment in east-central Nova Scotia; *in* Current Research 1994-D, Geological Survey of Canada, p. 89-94.

Goodman, N. R. 1952: Gypsum and anhydrite in Nova Scotia; Nova Scotia Department of Mines, Memoir No. 1, 75 p.

Holleman, M. 1976: The nature, origin and distribution of chloride in the lower B Subzone evaporites of Little Narrows, Victoria County, Nova Scotia; M. Sc. thesis, Acadia University, Wolfville, Nova Scotia.

Lewis, W. L. and Holleman, M. 1983: Gypsum in Atlantic Canada; Ontario Geological Survey, Miscellaneous Paper 114, Toronto, p. 79-95.

Lynch, G. and Giles, P. S. 1995: The Ainslie Detachment: A regional flat-lying extensional fault in the Carboniferous evaporitic Maritimes Basin of Nova Scotia, Canada; Canadian Journal of Earth Sciences, v. 33, p. 169-181.

Lynch, G., Keller, J. V. A. and Giles, P. S. 1998: Influence of the Ainslie Detachment on the stratigraphy of the Maritimes Basin and mineralization in the Windsor Group of northern Nova Scotia, Canada; Economic Geology, v. 93, p. 703-718.

Moore, R. G. 1967: Lithostratigraphic units in the upper part of the Windsor Group, Minas Sub-basin, Nova Scotia; *in* Collected Papers on the Geology of the Atlantic Region; Geological Association of Canada, Special Paper No. 4, p. 245-266.

Schenk, P. E. 1969: Carbonate-sulphate-redbed facies and cyclic sedimentation of the Windsorian Stage (Middle Carboniferous), Maritime Provinces; Canadian Journal of Earth Sciences, v. 6, no. 5, p. 1037-1066.

Schenk, P. E. 1984: Carbonate-sulfate relations in the Windsor Group, central Nova Scotia, Canada; *in* Ninth International Congress on Carboniferous Stratigraphy and Geology, Compte Rendu, v. 3, p. 143-162.

Wilson, G. A. and Sharpe, R. D. 1994: Quarrying operations of the Little Narrows Gypsum Company, Victoria County, Cape Breton Island, Nova Scotia, Canada; *in* Guide Book, Field Trip #4, Industrial Minerals in Nova Scotia, 30th Forum on the Geology of Industrial Minerals (1994), p. 22-30.

Preliminary Report on the Geology of the St. Patricks Channel Salt Deposit (NTS 11K/02), Victoria County, Cape Breton Island, Nova Scotia[1]

R. C. Boehner and P. S. Giles[2]

Introduction

The St. Patricks Channel area is situated approximately 15 km southwest of Baddeck, Victoria County, in central Cape Breton (Figs. 1 and 2). The geology in the vicinity was mapped and described by Kelley (1967), including the Whycocomagh and Baddeck map areas (NTS 11F/14 and 11K/02), and by Weeks (1955) in the Grand Narrows area (NTS 11F/15). The area is also included in recent mapping of NTS area 11K/02 by Lynch and Lafrance (1996).

Although there is a long history of investigation of the indicators of salt deposits in the area (Boehner, 1986), including salt springs and seeps described in Cole (1930) and Hayes (1931), it was not until 1981 that salt was defined in exploration drilling at MacIvers (McIvor) Point by Chevron (1982). Trace salt was known from the deeper parts of the Canadian Gypsum Company Little Narrows gypsum quarries where it occurs in association with anhydrite near the gypsum to anhydrite transition zone (Holleman, 1976).

Geology

Salt was intersected by Chevron (1982) in drillhole R1/R1W at MacIvers (McIvor) Point, located near the centre of a substantial Bouguer gravity low anomaly in the St. Patricks Channel area 25 km northeast of the Orangedale salt deposit (Figs. 1, 2 and 3). This exploration was part of an extensive potash exploration program by Chevron that focused on the Malagawatch salt deposit, located approximately 20 km to the south. Due to drilling difficulties, the drillhole required the drilling of an overlapping 'wedge' interval in the lower parts to get to the final depth (e.g. R1 and R1W). The salt-bearing section was intersected from 395.7 to 1174 m (1301-3853 ft.). The drillhole deviation from vertical is substantial, with 21 to 24 degrees reported near the bottom of the hole (no azimuth direction was reported). Note that bedding dips reported from the core sections are based upon measurements with respect to the horizontal core angle and not to the core axis. True dips of the strata, therefore, may be more or less depending upon the amount of hole deviation from vertical and the azimuth direction of deviation (unknown) with respect to the bedding dip direction(s).

In summary, drillhole R1/R1W intersected an upright and relatively continuous and complete section of the C Subzone (Major Cycle 3) and B Subzone (Major Cycle 2) of the Windsor Group from 22.5 m to 395.7 m (Fig. 3). This section occurs entirely within the salt dissolution zone and consequently none of the original salt is preserved. The drilling intersected an antiformal fold axis at 490 m within the uppermost part of the main salt of Major Cycle 1. The lowermost section of Major Cycle 2 was intersected in a major synform from 577.9 m to 828 m. An attenuated section of the main salt was intersected from 828 m to 1169 m and the hole was stopped in the basal anhydrite of Major Cycle 1 at 1185.7 m.

The drilled section contains the following units and structures in descending order (Fig. 3). The lower part of the Upper Windsor (Major Cycle 3) was intersected in the cored interval from 22.5 m to the base of the Herbert River Limestone Member at approximately 180 m. Bedding dips in this right-way-up section are at approximately 30 to 40

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Boehner, R. C. and Giles, P. S. 2003: *in* Mineral Resources Branch, Report of Activities 2002; Nova Scotia Department of Natural Resources, Report 2003-1, p. 25-32.

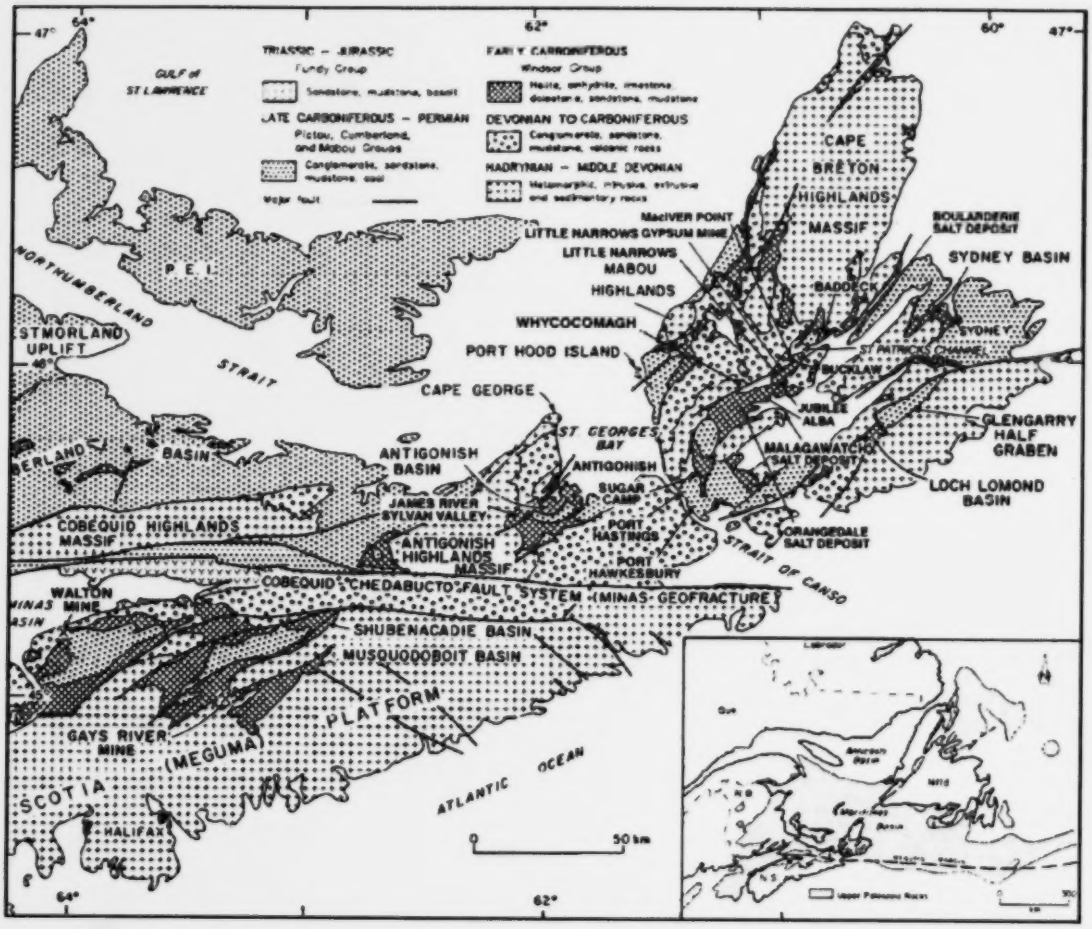


Figure 1. General geology and location map, south-central Cape Breton Island.

degrees. A relatively complete section of the Middle Windsor (B Subzone - Major Cycle 2) was then intersected to a depth of 395.7 m. The 'Triplet Marker' section described by Cook and Giles (2001) in the middle part of the Major Cycle 2 section of the Orangedale salt deposit is interpreted to occur in R1/R1W at a depth of 294.4 to 311.2 m. Bedding dips in this right-way-up section are approximately 20 to 30 degrees. Similar to the Malagawatch and Orangedale deposits (Giles, 2001 and Cook and Giles, 2001), all the salt strata were removed by dissolution in the near-surface environment (typically at depths above 400 m). Salt typically dominates Major Cycle 2 (530 m thick and 55% salt) and is abundant in Major Cycles 3 to 5 (470 m thick and 36% salt).

The uppermost part of the main salt section in Major Cycle 1, with a large component of mudrock as interbeds and inclusions, was intersected from 395.7 m to 577.9 m. An antiformal fold axis is located at an approximate depth of 490 m, where the section is repeated in the overturned fold limb. A thin carnallite potash unit within the generally muddy and dark-colored salt section defines this fold repeat. Bedding dips in this fold-repeated section of Major Cycle 1 are approximately 20 to 30 degrees.

The overturned fold limb continues down from the base of the overturned Major Cycle 2 at 577.9 m to a major synformal fold axis at a depth of approximately 773 m. This major synformal

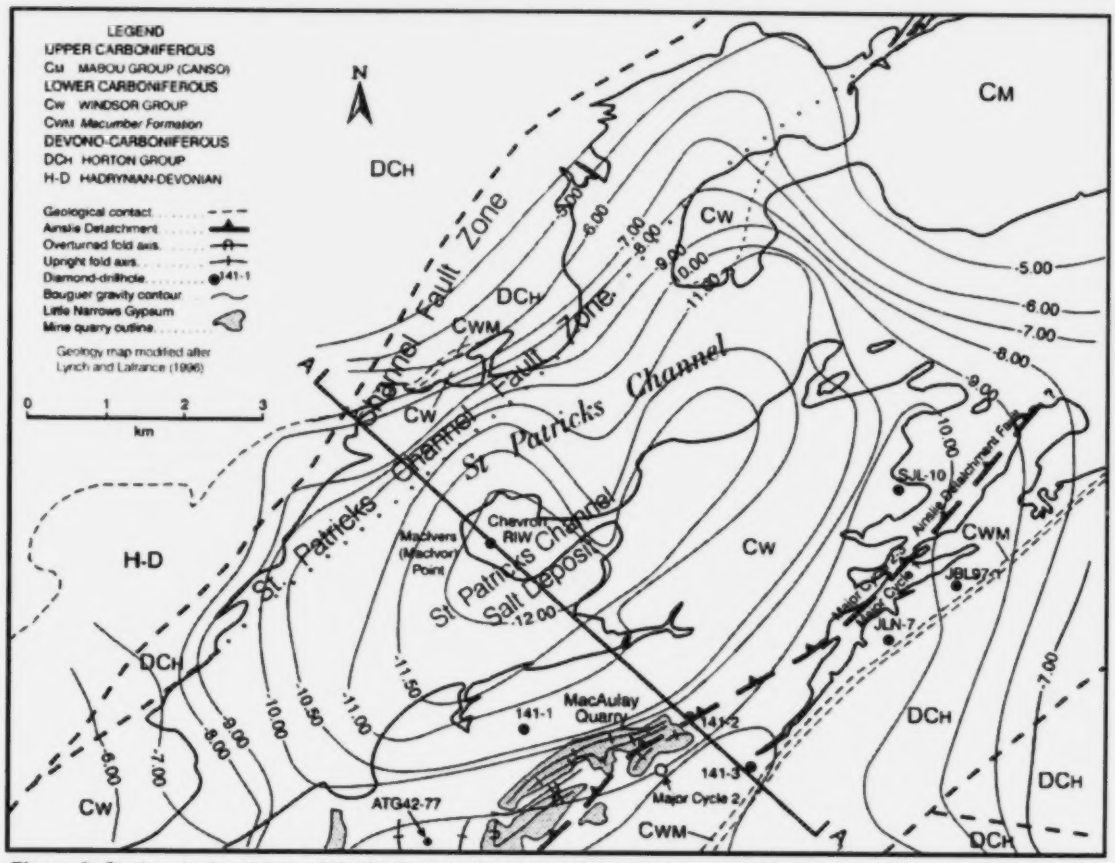


Figure 2. Geology in the vicinity of the St. Patricks Channel salt deposit, Inverness County.

structure repeats the lower part of Major Cycle 2. Two related minor antiformal folds at approximate depths of 697 m and 828 m symmetrically repeat a thin interval of anhydrite and salt units of the middle Windsor (B Subzone - Major Cycle 2) in a 'M' shaped fold. The upright lower fold limb continues down from 828 m to the base of Major Cycle 2 at approximately 1008 m. Bedding dips in this large, overturned fold structure in Major Cycle 2 between 577.9 m and 1008 m are approximately 30 to 50 degrees. The moderate to low-angle bedding dips indicate that the fold structures (limbs and fold axial planes) intersected in R1/R1W are also probably low angle, and approximately recumbent and isoclinal. This would be consistent with folds mapped in the Little Narrows gypsum quarries by Wilson and Sharpe (1994). The fold vergence direction for R1/R1W has been assumed to be congruent with folds in the quarries, with axial planes generally dipping to the northwest (Fig. 3).

A relatively thin interval of structurally disturbed salt and mudstone/salt breccia of the Major Cycle 1 main salt was intersected at 1008 m to 1169 m, and the basal anhydrite of Major Cycle 1 was intersected from 1169 m to the total depth of the hole at 1185.7 m. The stratigraphic thickness of the main salt typically exceeds 200 m and may be up to 300 m (Boularderie salt deposit, Boehner, 1986). Much of this thickness is inferred to be absent in R1/R1W due to structural removal and attenuation thinning due to the deformation associated with the decollement fault detachment zone at the top of the basal anhydrite of Major Cycle 1. Bedding dips in this multiple folded section are approximately 15 to 20 degrees.

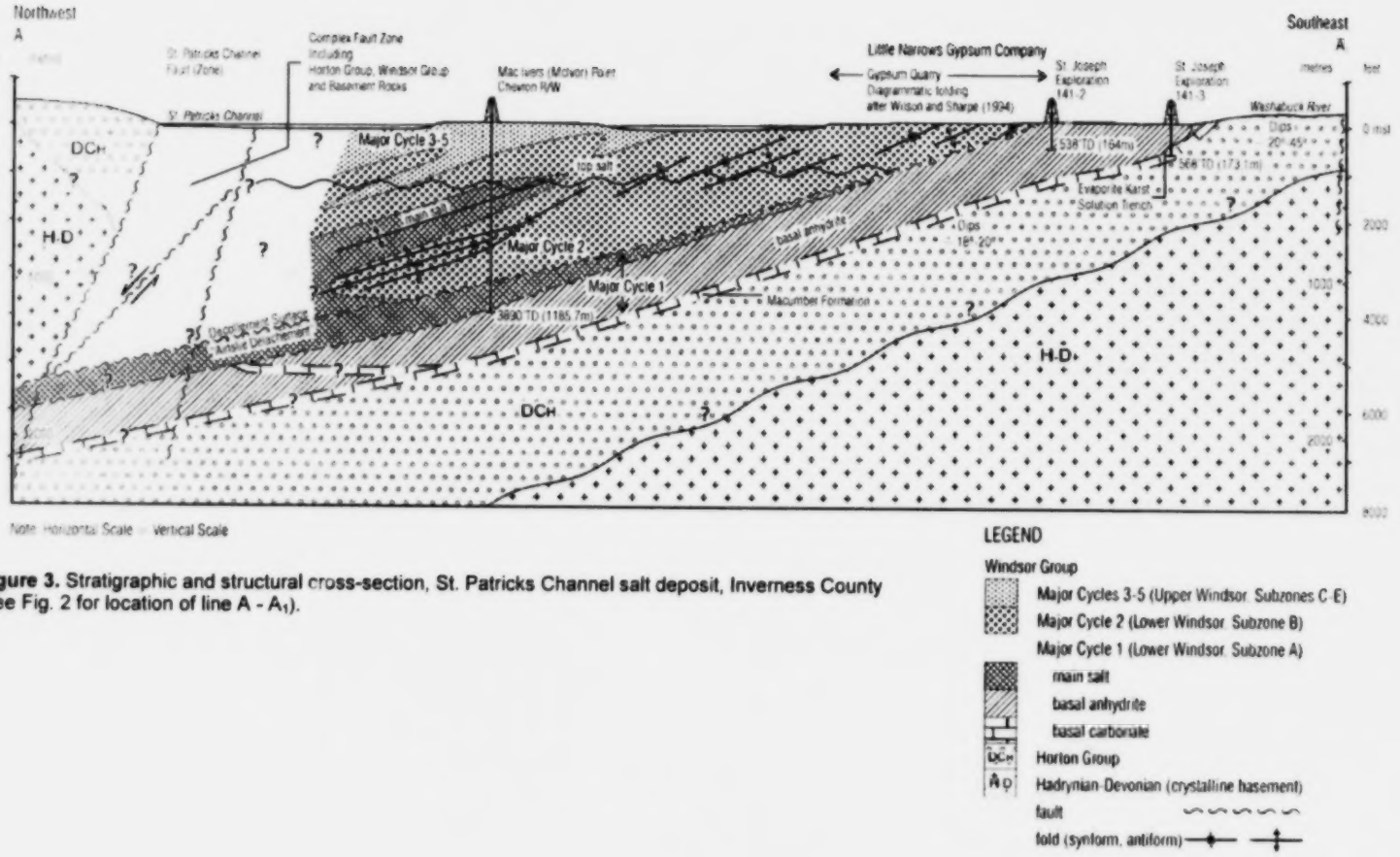


Figure 3. Stratigraphic and structural cross-section, St. Patricks Channel salt deposit, Inverness County (see Fig. 2 for location of line A - A_1).

The contact zone of the folded Major Cycle 2 section and attenuated main salt of Major Cycle 1 is inferred to be a major decollment zone (Fig. 3) that extends up dip to the southeast into the equally disturbed (folded, faulted and hydrated) evaporite section that is currently mined for gypsum by CGC Little Narrows Gypsum at Little Narrows (Wilson and Sharpe, 1994). The structural attenuation or shear faulting in this detachment zone has been previously described by Boehner (1992) and Giles and Lynch (Ainslie Detachment, 1994). Consequently, there is potential for potash and thicker sections of salt in the St. Patricks Channel area due to its geological similarity to the Boularderie salt deposit, which contains significant intersections of potash and is located approximately 20 km to the northeast.

The section intersected in drillhole R1/R1W is correlated with the Malagawatch stratigraphic section established by Chevron (1982) and Giles (2001). The stratigraphic units in R1/R1W representing the lower part of Major Cycle 2 (intersected three times due to folding) appear to be very similar to the Little Narrows gypsum mine section (MacAulay Quarry) of carbonates, gypsum/anhydrite and redbeds described by Wilson and Sharpe (1994). These include an un-named carbonate at the base and overlying limestone/dolostone units including the Hazeldale, Cains Mountain, and Magazine units. These correlate approximately with the Chevron (1982) stratigraphic markers 4-8, 4-7, 4-6, and 4-4.

Exploration seismic surveys and diamond-drilling for base metal deposits in the late 1990s by Savage Resources (Jubilee Joint Venture, 1998a, b) have contributed substantially to the data available on the subsurface geology in the Jubilee and Little Narrows area. They have established the occurrence of the Macumber Formation basal carbonate and thick basal anhydrite section typical of Major Cycle 1 units to depths of 500 m. In addition, the section drilled in SJL97-3 by Jubilee Joint Venture (1998b), southwest of the Little Narrows gypsum mine (Fig. 2), included up to 170 m of interstratified and folded (recumbent) gypsum, anhydrite, salt, carbonate and siliciclastics. This section probably correlates with the Little Narrows Gypsum mine section (Wilson and Sharpe, 1994). Related exploration drilling by Jubilee Joint Venture (1998) has also established the presence of sheared pre-Carboniferous basement units on the peninsula south of Bucklaw, near the Little Narrows water supply (located approximately 1.5 km to the north of SJL97-3). This area was indicated on previous geological maps by Kelley (1967) and Lynch and Lafrance (1996) to be underlain by the Windsor Group, although no outcrop was identified.

The implication is that the contact between the Carboniferous Windsor Group and older rocks must be relocated approximately 1 km to the southeast from its current position on the maps of Kelly (1967) and Lynch and Lafrance (1996). Although this is not a large distance, geological map interpretations have generally associated lowland topography with the distribution of Carboniferous rocks, especially the Windsor Group. It is also apparent that there are anomalies in the variety of rocks mapped along the strike of the major fault bordering the north side of the Carboniferous basin. These include basement rocks juxtaposed with basin rocks in patterns typical of faulted relationships. These maps and the deep drilling in the area (R1/R1W) indicate that the St. Patricks Channel Fault probably is a system of faults (fault zone) and has relative dip-slip in excess of 1.5 km. It is likely to be steep near surface, and perhaps a reverse fault or possibly a thrust at depth (Fig. 3).

Geophysics

The area in the vicinity of St. Patricks Channel salt deposit is included on a Chevron Bouguer anomaly map (Chevron, 1982). The discovery drillhole (R1/R1W) is situated near the center of a narrow northeastward-trending gravity trough centered beneath St. Patricks Channel between Little Narrows and Nyanza (Figs. 1 and 2). The salt mass presumed to have produced the gravity low has been defined only by this drillhole. The Bouguer anomaly indicates the structure may continue several kilometres to the northeast toward Baddeck and into the Baddeck River valley. It appears to be bounded to the southwest by an area of coincident magnetic and gravity high near Alba, approximately 8 km south of Little Narrows. A

subdued gravity high extends from Little Narrows and Jubilee southwest to Alba. Steep contours are evident along the northwestern side of the St. Patricks Channel gravity low at the faulted boundary with Horton Group and pre-Carboniferous basement rocks in the adjoining highlands. Exploration seismic surveys and potential field maps were utilized to delineate diamond-drilling targets for base metal deposits in the Jubilee and Little Narrows area. The most recent work was completed in the late 1990s by Savage Resources (Jubilee Joint Venture, 1998a, b and 1999). Gravity and magnetic field data have been mapped and modelled in the area by King (2003, in press).

Economic Geology

The St. Patricks Channel salt deposit is presently defined in only one deep exploratory drillhole located on a moderate amplitude Bouguer gravity anomaly. Little Narrows is located near the southern end of St. Patricks Channel approximately 2 km south of Bucklaw, and 8 km east-northeast of Whycocomagh (Figs. 1 and 2). Significant sections of salt were intersected at the St. Patricks Channel Site in a complex folded structure typical of the saline Windsor Group sections in south-central Cape Breton Island. Anhydrite, siltstone, dolostone and limestone are interbedded with the salt in sections representing the lower to middle part of Major Cycle 2. A thin, structurally attenuated section of the main salt unit of Major Cycle 1 was intersected from approximately 1008 m to 1169 m. The main potash zone associated with this stratigraphic unit was not present in R1/R1W. The section of the lower Major Cycle 2 correlates with similar sections at the Malagawatch and Orangedale salt deposits and is characterized by a low content of salt.

The lower part of the recumbently folded Major Cycle 2 section probably correlates up-dip to the southeast with the CGC Little Narrows Gypsum Mine section described by Wilson and Sharpe (1994). Salt present in the deep subsurface has been removed by groundwater dissolution in the near-surface environment and anhydrite has been hydrated to gypsum. Salt in minor, erratically distributed impurity zones has been encountered in certain parts of the gypsum mine, especially in the deeper parts in association with anhydrite. The distribution and chemistry of the salt occurrences in the gypsum mine were studied and described by Holleman (1976) in an unpublished M.Sc. thesis at Acadia University. Deep drilling down-dip of the gypsum mine by Chevron at MacIvers (McIvor) Point (R1W) intersected substantial salt in the unhydrated correlative stratigraphic section of the Lower Windsor. Salt dissolution, and hydration of anhydrite to gypsum, in the Windsor Group generally occur in the subsurface above depths of 300 m. Hydration of anhydrite to gypsum generally occurs at shallower depths than the salt dissolution zone, which extends to a depth of nearly 400 m at MacIvers (McIvor) Point.

Two thin zones of low-grade potash salts including carnallite were intersected in R1/R1W. These occur as a fold-repeat section of the uppermost part of the main salt section of Major Cycle 1. Carnallite with sylvite is also known in a similar section in the Boularderie salt deposit located 23 km to the northeast, as well as in the Orangedale (Ashfield) salt deposit located 23 km to the southwest. The main salt section of Major Cycle 1 is the most prospective potash and salt target in the region and the section intersected in R1W is highly attenuated and structurally incomplete. This is in part due to removal and disruption by the Ainslie Detachment, a regional detachment fault. The depth to the top of the salt section is 396 m, which is typical for deposits in the region.

Brine springs and seeps indicative of subsurface solution, have been reported and documented in the Bucklaw and Baddeck area immediately to the north and west. Further exploration and possible development of the St. Patricks Channel salt deposit may be hindered because the major portion of the salt structure occurs beneath St. Patricks Channel. The intersection of the attenuated main salt of Major Cycle 1 (approximately 160 m thick) near the bottom of R1/R1W may be economically significant. The salt-bearing sections in Major Cycle 2 in R1/R1W are relatively thin and less economically attractive. The extension of the deposit into the Baddeck area to the northeast may

be prospective for further exploration. The St. Patricks Channel salt deposit is advantageously situated close to tide-water shipping in the Little Narrows area.

References

Boehner, R. C. 1986: Salt and Potash Resources in Nova Scotia; Nova Scotia Department of Mines and Energy, Bulletin No. 5, 346 p.

Boehner, R. C. 1992: An overview of the role of evaporites in the structural development of Carboniferous basins in Nova Scotia; *in* Nova Scotia Department of Natural Resources, Mines and Energy Branch, Report of Activities 1991, ed. D. R. MacDonald; Nova Scotia Department of Natural Resources, Mines and Energy Branch Report 92-1, p. 39-56.

Chevron Standard Ltd. 1982: The Malagawatch potash exploration program, 1980-1981, Cape Breton, Nova Scotia: Nova Scotia Department of Natural Resources, AFR 11F/15B, 40-J-36(02).

Cole, L. H. 1930: Potash salts in the Maritime Provinces of Canada; *in* Investigations of Mineral Resources and the Mining Industry, 1928; Department of Mines, Canada, Mines Branch, Publication no. 710, p. 19-27.

Cook, L. and Giles, P. S. 2001: Stratigraphy and structure of the Orangedale Salt Deposit, Windsor Group, central Cape Breton Island; *in* Mining Matters for Nova Scotia, Opportunities for Economic Development, ed. D. R. MacDonald; Nova Scotia Department of Natural Resources, Minerals and Energy Branch, Report ME 2001-2, p. 4.

Giles, P. S. 2001: Stratigraphy and structure of the Malagawatch Salt Deposit; *in* Mining Matters for Nova Scotia, Opportunities for Economic Development, ed. D. R. MacDonald; Nova Scotia Department of Natural Resources, Minerals and Energy Branch, Report ME 2001-2, p. 10.

Giles, P. S. and Lynch, G. 1994: Stratigraphic omission across the Ainslie Detachment in east-central Nova Scotia; in Current Research 1994-D, Geological Survey of Canada, p. 89-94.

Hayes, A. O. 1931: Report on the potash possibilities of Nova Scotia; *in* Annual Report on the Mines, 1930, Part 2; Nova Scotia Department of Mines, 147 p.

Holleman, M. 1976: The nature, origin and distribution of chloride in the lower B Subzone evaporites of Little Narrows, Victoria County, Nova Scotia; M. Sc. thesis, Acadia University, Wolfville, Nova Scotia.

Jubilee Joint Venture 1999: Assessment report on 1998 exploration programs, Mineral Exploration Licences 02218 and02283, Map Sheet 11K/02B, Washabuck Area, Victoria County, Nova Scotia, Michael Cullen; Nova Scotia Department of Natural Resources AR 99-034.

Jubilee Joint Venture 1998a: Assessment report on 1998 exploration programs, Mineral Exploration Licences 03130, 2664, 221 and 167, Map Sheet 11K/02B, Dena's Pond, Jubilee, Caines Mountain Areas, Victoria and Inverness Counties, Nova Scotia, Michael Cullen; Nova Scotia Department of Natural Resources AR 98-116.

Jubilee Joint Venture 1998b: Assessment report on 1998 exploration programs, Mineral Exploration Licences 02218 and 02283, Map Sheet 11K/02B, Washabuck and Little Narrows Areas, Victoria and Inverness Counties, Nova Scotia, Michael Cullen; Nova Scotia Department of Natural Resources AR 98-056.

Kelley, D. G. 1967: Baddeck and Whycocomagh map areas with emphasis on Mississippian stratigraphy of central Cape Breton Island, Nova Scotia; Geological Survey of Canada, Memoir 351.

King, M. S. 2003 in press: Contractor's Report, Targeted Geoscience Initiative (TGI), Southern Cape Breton Island, Potential Field Modelling Project; Nova Scotia Department of Natural Resources, Open File Report.

Lynch, G. and Lafrance, B. 1996: Bedrock Geology, Baddeck, 11K/02, Cape Breton Island, Nova Scotia; Geological Survey of Canada, Open File Map 2488, scale 1:50 000.

Weeks, L. J. 1955: Grand Narrows, Cape Breton, Richmond, Victoria and Inverness Counties, Cape Breton Island; Geological Survey of Canada, Map 1040A, scale 1:63 360.

Wilson, G. A. and Sharpe, R. D. 1994: Quarrying Operations of the Little Narrows Gypsum Company, Victoria County, Cape Breton Island, Nova Scotia, Canada; *in* Guide Book, Field Trip #4, Industrial Minerals in Nova Scotia, 30th Forum on the Geology of Industrial Minerals (1994), p. 22-30.

Mineral Inventory Studies in Cape Breton Island

G. J. DeMont

Mineral Occurrence Database Activities

Completion of the Mineral Occurrence Database compilation for the Targeted Geoscience Initiative Project study area was the focus of the Cape Breton Island Mineral Inventory Studies Project in 2002. Version 6 of the Mineral Occurrence Database, released in December 2002, includes numerous new and updated occurrence records for NTS map areas 11F/14 and 11F/11. Initially, the Targeted Geoscience Initiative (TGI) studies were restricted to these two map sheets, but the study area was expanded in 2002 to include the west half of 11F/10 and a small corner of 11F/15 (Fig. 1). Metallic mineral occurrence records for most of Cape Breton Island, including the TGI study area, were completed prior to the commencement of the TGI project, but new data from the mineral exploration assessment files continue to be compiled and added to the database as they become available.

Literature compilation of Mineral Occurrences Database Records continued in 2002-2003, with the addition of nine new industrial mineral occurrence records. A review of the available literature for the TGI Project study area continues, so the addition of more records to the database is expected before Version 7 of the database is released in April 2003.

Carbonate Resource Studies

Resource mapping surveys and mineral inventory site visits were completed on the Glenn Brook, Lamey Brook, MacEachern Road, Skye Mountain and Kewstoke Brook carbonate deposits. New data collected at these sites in 2002 have been compiled and added to the Mineral Occurrences Database. In addition, 1:20 000 scale carbonate resource maps are being produced in ArcView® for the Glen Brook, Lamey Brook and MacEachern Road deposits. The updated database and resource maps will be released with the TGI Project final report in 2003.

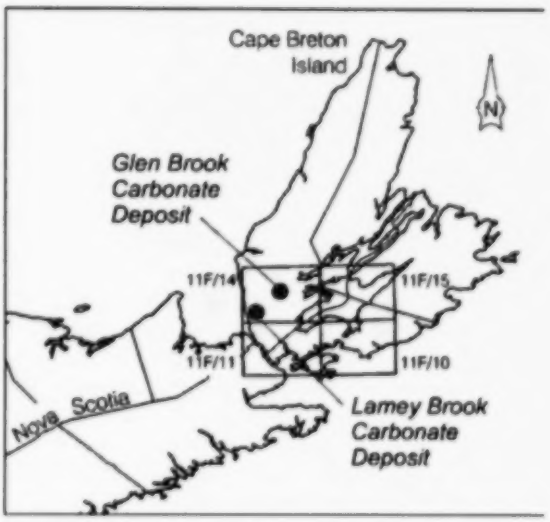


Figure 1. Location of the 2002 study area in Cape Breton Island, including the Glen Brook and Lamey Brook carbonate deposits.

The detailed resource mapping surveys provided considerable new insight into the geology of the carbonate deposits. Analysis of rock samples collected as part of this study also help to identify the various grades of dolomite and limestone resources found at these sites. A summary of new information from resource mapping surveys of two of the carbonate deposits are provided below.

Glen Brook

Milligan's (1967) geological map of the Creignish Hills illustrates the occurrence of a large area of white to blue-white limestone along the north side of Glen Brook (formerly Diogenes Brook). This limestone unit, which is part of the Precambrian Blues Brook Formation (formerly George River Group), was the focus of a detailed resource mapping survey undertaken in 2002.

DeMont, G. J. 2003: *in* Mineral Resources Branch, Report of Activities 2002; Nova Scotia Department of Natural Resources, Report 2003-1, p. 33-35

Extensive carbonate outcrops are exposed along the north side of Glen Brook, on the side of a 100+ m high south-facing slope. The outcrops are composed of two principal rock types: (1) blue to grey limestone, and (2) buff, grey and white dolomite or magnesian-limestones. These occur as distinct units which are readily mappable in the field.

Other rock units found in the study area include green mafic volcanics, grey quartzite or greywacke, tan feldspathic quartzite, white quartzite and granite. The white quartzite is difficult to distinguish from white dolomite in areas where the two are in contact, as they have similar colour, texture and grain size.

Grey to black siltstone and shale are interbedded in the limestone. The areal extent and volumes of these two rock types are difficult to estimate because they are subject to deep preferential weathering and, therefore, are poorly exposed. This is a resource mapping problem, because the siltstones and shales are mostly covered by overburden and difficult to detect on the steep slope, hence giving the false impression that the slope is underlain entirely by limestone.

The carbonate rocks illustrated on Milligan's (1967) map occur in a northeast-trending band, sub-parallel to the east-west Glen Brook Valley. Traverse lines for the 1967 mapping survey were primarily restricted to brook valleys and roads. Numerous cross-country traverse lines, completed as part of the 2002 resource mapping survey, provided abundant new outcrop data which allow for a different interpretation of the local geology. Along the north side of Glen Brook, bedding was found to trend northwest to west-northwest, with steep north dips. The bulk of the carbonate rocks exposed here are either dolomite or magnesian-limestone, with limestone constituting <30% of the total carbonate outcrops. The Diogenes Brook (now called Glen Brook) Cave is found in a narrow limestone bed along the west side of the study area.

Metamorphic grade of the Blues Brook Formation appears low, likely lower greenschist facies, because no metamorphic minerals are apparent in hand specimens collected in this area. The metamorphic grade is even low in areas adjacent to granite bodies.

Considerable grain size variation was observed in the carbonate rocks. The buff to white dolomite is generally medium- to coarse-grained, but grey dolomite and limestone are usually fine grained. Further studies are required to determine the reason for this variation, but preliminary observations suggest that it could be reflecting variances in the primary crystal grain size. Metamorphic recrystallization is also considered to be a factor locally, particularly near contacts with the granite dykes.

Analysis of samples collected from the various limestone beds suggests that high calcium stone is found here, but the presence of interbedded siliclastic rocks place constraints on the mineable widths of clean limestone beds. This unfortunately may diminish the economic viability of opening a quarry at this location. Mapping has indicated that large volumes of white dolomite or magnesian-limestone occur in this area. These rocks could be an interesting exploration target if markets are found for a high brightness carbonate filler.

Lamey Brook

The Lamey Brook carbonate deposit is illustrated on Fletcher's (1884) geological map, but a mineral exploration assessment report search suggested that it has never been explored. This discovery came as a bit of a surprise, because the deposit's proximity to the Point Tupper ship-loading facilities should make it an excellent exploration target.

The detailed resource mapping survey outlined a large deposit of grey, white and buff dolomite or magnesian-limestone. These rocks are part of the Precambrian Blues Brook Formation (formerly George River Group). Other rock units found in the Precambrian strata at Lamey Brook include grey quartzite, grey to black limestone, and mafic dykes.

A white rock composed of brecciated, coarse grained quartz was initially thought to be a distinct quartzite unit, but further mapping revealed that it is actually a vein. These veins are abundant locally and appear to penetrate the dolomite in intensely

fractured zones. Mafic dykes of unknown age are common in this deposit. An apparent lack of deformation in these dykes suggests they are younger than the Precambrian Blues Brook Formation rocks they intrude.

Pervasive red hematite alteration of the dolomite is common in some areas of the deposit, particularly along the south side of Lamey Brook. MacLeod Resources Limited staked the deposit and plans to explore these red zones further in 2003 to determine if they are suitable for production of red marble building stone blocks.

The economic possibilities for development of this deposit appear limited, because the bulk of it is composed of grey dolomite, a rock type which is unsuitable for most prospective carbonate markets. The best opportunity for development of this resource lies in the red marble building stone markets.

References

Fletcher, H. 1884: Geology, Island of Cape Breton; Geological Survey of Canada, Map No. 22, scale 1:63 360.

Milligan, G. C. 1967: Geological Map of the Creignish Hills; Nova Scotia Department of Mines, scale 1:31 680.

Digital Information Services

B. E. Fisher, J. C. Poole and J. D. MacNeil

The Digital Information Services group is responsible for developing and maintaining the Mineral Resources Branch (MRB) Geographic Information System and associated databases, the NovaScan bibliographic geoscience database, for supplying digital data and services to clients and staff, and for developing the MRB web site. Permanent Digital Information Services staff consist of geologists/GIS specialists Brian Fisher and Jeff Poole, and web technician Susan Saunders. Adam Sherry, a geology student, was hired to work with the group on casual basis over the past year. John MacNeil, geologist/GIS specialist, and Miranda Huskins, geologist, were hired in November 2000 to work on the Targeted Geoscience Initiative (TGI) project in south-central Cape Breton Island. Jeff McKinnon, geologist/GIS Specialist, was hired as a GIS Assistant for five months, and then for an additional six months on the Metadata Catalogue Project

Digital Geoscience Data Products

A collection of digital geology maps, databases and images of Nova Scotia (in DXF, ARC export, ArcView® shapefiles, TIFF, and JPEG formats in a UTM projection using the NAD27 datum, and in PDF format) has been developed and is now on sale through the library and available for free download from the MRB web site at http://www.gov.ns.ca/natr/MRB/pub3.htm. The complete list of digital data products available can be seen in Appendix 2. This list can be obtained from the Halifax DNR Library or viewed on the MRB web site at http://www.gov.ns.ca/natr/MRB/pubshome.htm. A licence agreement is issued with all digital data sets. This agreement allows unrestricted use of the data with the understanding the DNR remains the owner of the data and is not transferring copyright to the user. Since March 1999, when the data were first made available for download from the MRB web site, there has been nearly 40,000 downloads.

Public Access GIS

A Public Access GIS has been developed for the use of clients in the Halifax library. This is a user-friendly query and display system that uses a customized version of ArcView® to access a variety of geographically referenced digital geoscience data on Nova Scotia. It can display and query data sets, overlay various themes of geoscience, topographic and land-use information, and output the resulting maps as colored plots. Version 3 of the Public Access GIS is currently being worked on and will contain many new themes and an improved menu system. This version should be available in 2003.

GIS Development

Digital Information Services staff have been working cooperatively with MRB staff on several projects including releasing version 1 and creating version 2 of the Mineral Resource Land Use Maps. The 98 1:50 000 maps were released as PDFs on the Branch web site.

The drillholes database is currently being re-designed and a data entry application being developed. This work should be completed in 2003.

The GIS version of the Registry of Mineral and Petroleum Titles database was updated several times. Three new versions (4, 5 and 6), of the Mineral Rights Disposition Map for the Province of Nova Scotia (OFM ME 2000-6) were released. A digital product has been created from the Registry database, and should be released in 2003.

Work is continuing on converting the NovaScan database into ArcInfo® format. When completed, the database will be made available in the Public Access GIS and on the internet in 2003.

Work has continued on converting 48 recently published bedrock geology maps and

Fisher, B. E., Poole, J. C. and MacNeil, J. D. 2003: *in* Mineral Resources Branch, Report of Activities 2002; Nova Scotia Department of Natural Resources, Report 2003-1, p. 37-39.

approximately 30 of the Faribault geological series maps from Fieldlog®/AutoCAD® format into ArcInfo® and incorporated as part of our GIS. These maps will be completed and released as digital products in 2003.

Internet Map Projects

Jeff Poole has created several prototype Internet Map Server (IMS) applications, currently running in-house, that will allow our clients to view, query, plot and download our digital maps and databases over the internet. Over the next year Jeff will be committing much of his time to producing an internet application, using ArcIMS technology, that will provide the general public with internet access to our Public Access GIS layers. It is planned that the initial deployment of this application will be in 2003.

Targeted Geoscience Initiative (TGI) Project in South-central Cape Breton Island

In the summer of 2000 Natural Resources Canada and the Mineral Resources Branch were awarded funding under the Geological Survey of Canada Targeted Geoscience Initiative (TGI) for a geological mapping project to aid in mineral development in south-central Cape Breton Island. As part of this project, the group is responsible for producing a digital compilation of geological data for this area. John MacNeil and Miranda Huskins were hired in November 2000 to work exclusively on this project to build databases, digitize maps and develop the digital products that will be produced as a result of this project. We have identified approximately 90 layers that may potentially be included as part of the final products for this project. To date approximately 20 maps have been digitized, several maps have been scanned, geophysical images created, and a number of other layers and databases have been developed for inclusion in the compilation. A web site for the project is currently under development.

Canadian Geoscience Knowledge Network

The Canadian Geoscience Knowledge Network (CGKN) is a collaborative effort between the 12 provincial and territorial geoscience agencies and the Geological Survey of Canada, which operates six offices across Canada. The plan is for the CGKN to be a single window of access, using the internet, to access the geoscience holdings of all the surveys. In November Mineral Resources Branch received funding from the CGKN Metadata Catalogue Project to continue development of its metadata server and continue developing metadata to describe digital data products and publications, which will be searchable over the internet by CeoNET and the CGKN metadata search engine. The funds received were used to hire Jeff McKinnon to work on this project for four months from December 2002 - March 31, 2003.

Digital Products Released in 2002

The following new digital products and updated versions were released in 2002. These can all be downloaded for free from the URL listed with the product.

DP ME 50. Geological Map of Central Musquodoboit (Part of NTS. SHEET 11E/03), Halifax and Colchester Counties, Nova Scotia, 2002, by R. J. Horne and M. S. King, scale 1:20 000. Open File Map ME 2002-1 (http:// www.gov.ns.ca/natr/meb/download/dp050.htm)

DP ME 49. Map of Land Use Constraints in the Halifax-Dartmouth Metropolitan Area, Nova Scotia, 2001, compiled by G. Prime, scale 1:100 000. Open File Map ME 2001-2. (http:// www.gov.ns.ca/natr/meb/download/dp049.htm)

DP ME 48. Map of Bedrock Aggregate Potential in the Halifax-Dartmouth Metropolitan Area, Nova Scotia, 2001, compiled by G. Prime, scale 1:100 000. Open File Map ME 2001-1. (http://www.gov.ns.ca/natr/meb/download/dp049.htm)

DP 001a. Mineral occurrence query program, version 2.1, February 2002. (This is a viewing and searching program with instructional manual (40 pages) for use with DP 001b Mineral Occurrence Database) (http://www.gov.ns.ca/natr/meb/download/dp001a.htm)

DP 001b. Mineral occurrence database, version 5, January 2002. This database can be used with DP 001a, the Mineral Occurrence Query Program. (http://www.gov.ns.ca/natr/meb/download/dp001b.htm)

DP 002. Mineral occurrence database, version 5, January 2002. (http://www.gov.ns.ca/natr/meb/download/dp002.htm)

DP ME 47. Mineral Resource Land-Use (MRLU) Maps, Nova Scotia, version 2, 2002, compiled by D. B. Hopper, F. J. Bonner, B. E. Fisher and A. N. Murphy, scale 1:50 000. Open File Map ME 2000-4. (http://www.gov.ns.ca/natr/meb/download/dp047v2.htm)

O00-06. Mineral Rights Disposition Map for the Province of Nova Scotia, version 5 (June 27, 2002) and version 6 (November 5, 2002), compiled by B. E. Fisher, I. M. MacLellan and A. S. Wenning, scale 1:500 000. Open File Map ME 2000-6. (http://www.gov.ns.ca/natr/meb/download/00o06.htm)

NovaScan

NovaScan is the bibliographic geoscience database on Nova Scotia and its offshore regions. As of December 31, 2002, the database contained 15,391 MRB records, consisting of 6770 mineral exploration assessment and property reports, 3713 publications, 2729 open files, 1200 journal literature references, 789 theses, 173 contribution series, 12 digital publications, and 5 outside publications.

NovaScan was updated with 455 new records in year 2002: 191 assessment and property reports, 184 publications, 35 open files, 12 contribution series and 33 theses. In 2002, 138 assessment and property reports were publicly released from confidential status. Each month, a list of open assessment and property reports was generated from NovaScan, distributed to the DNR Library, the Core Library in Stellarton, and to the three Regional Geologists in Coxheath, Bible Hill and Bridgewater, as well as posted on the MRB web site. Quarterly reports were produced and published in the *Nova Scotia Minerals Update* and on the web site.

In order to provide better service to our staff and clients by allowing internet access to and searching of the NovaScan database, two independent projects were continued in 2002. The first project involved downloading the database into the branch GIS and creating geographic boundaries for all NovaScan records. When complete, the NovaScan database will be searchable through the Public Access GIS, and also searchable on the internet. Completion of this project should take place in year 2003.

The second project involved downloading and converting the NovaScan records into standard library MARC format, so that they could be loaded into the Provincial Library's Internet-accessible *NcompasS* catalogue database. This catalogue can be accessed at the following address: http://ncompass.library.ns.ca. After selecting your language of choice (English/French), select Nova Scotia Department of Natural Resources from the available catalogue listings, and you will then be able to search all the DNR Library records including the NovaScan records. As of December 31, 2002, all non-confidential NovaScan records were entered into the *NcompasS* database. Newly released assessment reports, property reports, open files and publications are added to the *NcompasS* catalogue on a monthly basis.

Soil and Till Geochemistry of the Halifax Regional Municipality, Nova Scotia

T. A. Goodwin

Introduction

Historically, there has been a general lack of geochemical sample sites within or near the populated areas of the province. As the demand for new homes with rural settings increases, existing subdivisions are expanded and new subdivisions are built to meet this demand. Recent construction of new roads and basement excavations in the Halifax Regional Municipality (HRM) has created a unique opportunity to sample relatively undisturbed soil/till profiles, in the area (NTS 11D/11, 12, 13 and 14).

The objectives of the soil and till geochemical sampling program are to: (1) establish a historical geochemical baseline reference for the HRM area, (2) compliment a paper by Lewis *et al.* (1998) that describes the engineering and geotechnical characteristics of the surficial sediments of HRM, but didn't report on corresponding geochemical data, (3) compliment pre-existing regional geochemical data sets available at the Nova Scotia Department of Natural Resources (NSDNR), (4) demonstrate the existence of natural geochemical variability that characterizes different surficial units, and (5) demonstrate that by simply changing media type, sample collection depth, size fraction analyzed, or the acid digestion used, there will be associated variability with the reported analytical results. Newly exposed "fresh" outcrops often displayed ice flow indicators (e.g. striations) that were also mapped during the geochemical sampling program.

Geology and Geochemistry

Bedrock Geology

The Cambrian-Ordovician Meguma Group metasediments are the oldest rocks within the HRM study area. The Meguma Group consists of the metasandstone-dominated Goldenville Formation overlain by the slate-dominated Halifax Formation (Fig. 1).

Structurally, the metasediments are characterized by a series of northeast-trending anticlines and synclines and northwest-trending extensional structures (Lewis *et al.*, 1998). Regional greenschist to amphibolite facies metamorphism characterizes the Meguma Group metasediments; locally, contact auroles associated with granitoid intrusions are common (Lewis *et al.*, 1998).

Gold and arsenic occurrences characterize several former gold districts (e.g. Waverley) that occur within HRM (Environment Canada, 1985). Locally, slates of the Halifax Formation can contain high (up to 10%) but variable concentrations of sulphide, dominated by pyrite and pyrrhotite with lesser amounts of arsenopyrite, cobaltite, glaucodot, chalcopyrite and covellite (Haysom, 1994). Once exposed to the atmosphere, sulphide-rich slates are susceptible to alteration and may form acid surface waters, commonly referred to as acid rock drainage (ARD), which are very harmful to the environment.

The Meguma Group metasediments have been intruded by Devonian granodiorite, monzogranite and leucomonzogranite (MacDonald and Horne, 1987). These intrusive rocks, apart from being mineralogically and genetically distinct from the Meguma Group metasediments, are also distinct in the fact that they are characterized by their massive, non-foliated texture (MacDonald and Horne, 1987; Lewis *et al.*, 1998). Locally, variable quantities of sulphides associated with quart veins are present, as are granite-related pegmatite dykes and quartz greisens (MacDonald and Horne, 1987; Lewis *et al.*, 1998). Alteration includes but is not limited to large zones of cordierite enrichment plus local areas of moderate hematite, limonite,

Goodwin, T. A. 2003: *in* Mineral Resources Branch, Report of Activities 2002; Nova Scotia Department of Natural Resources, Report 2003-1, p. 41-47

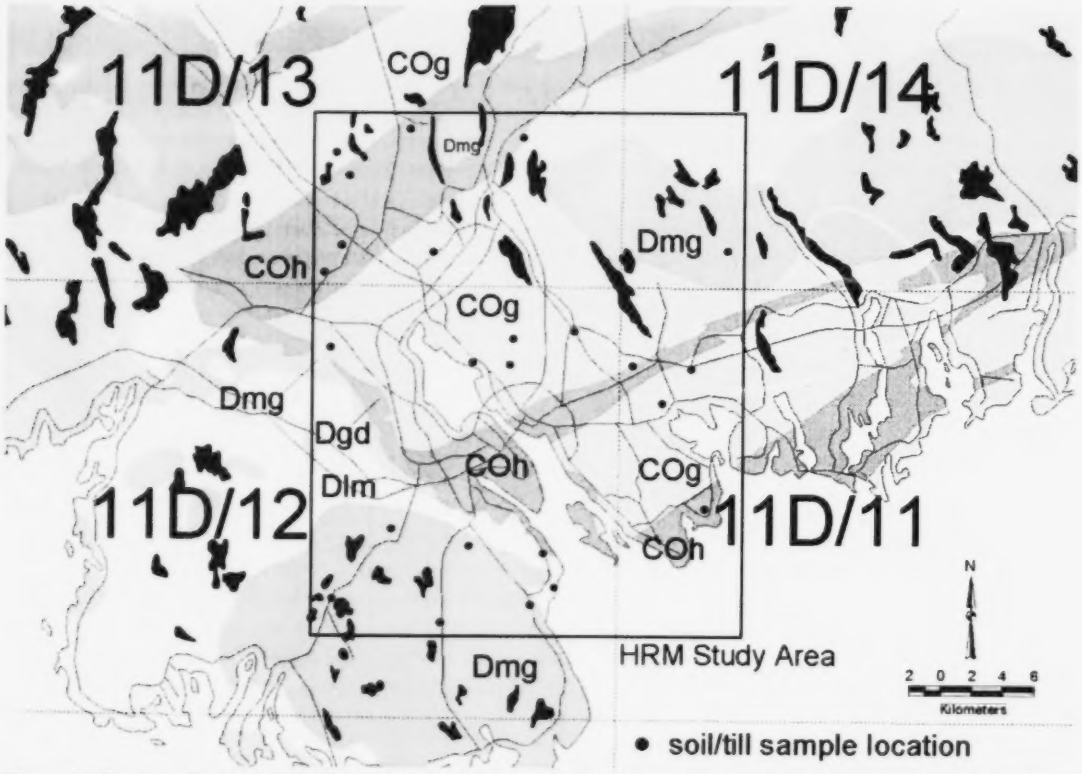


Figure 1. Geological map of the HRM study area. Geology modified from Keppie (2000). COg = Cambro-Ordovician Goldenville Formation, COh = Cambro-Ordovician Halifax Formation, Dmg = Devonian monzogranite, Dlm = Devonian leucomonzogranite and Dgd = Devonian granodiorite.

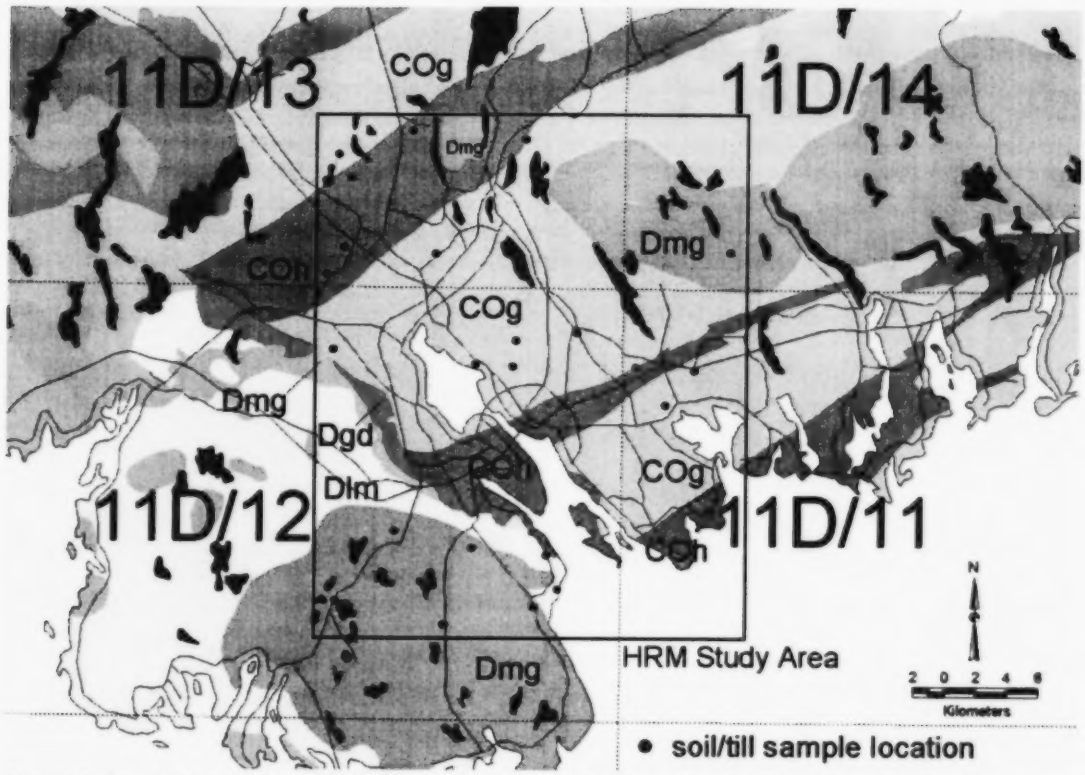
manganese, kaolinite and chlorite alteration (MacDonald and Horne, 1987).

Lewis *et al.* (1998) provide a detailed description on the geological setting of the HRM, including the lithology and structure of the Meguma Group metasediments and granitoid intrusives. Prime (2001) reported on the bedrock aggregate potential of HRM with respect to continued urban growth, as well as land-use and environmental issues.

Surficial Geology

Recent surficial mapping that included the HRM study area has been completed by Stea and Fowler (1979, 1981) and Finck and Graves (1987). Surficial sediments sampled within the current HRM study area include a local quartzite till derived from the Goldenville Formation metasandstone, slate till derived from the Halifax Formation slate, and granite till derived from intrusive granitoid rocks (Stea and Fowler, 1979, 1981). Distally derived Lawrencetown Till, including ground moraine and drumlins, also covers a large part of the study area (Stea and Fowler, 1979, 1981). Large areas of bedrock-dominated terrain characterized by thin till cover are also common, particularly over the granite terrain. A summary of the Tertiary and Quaternary geology of HRM is presented in Lewis *et al.* (1998).

Mapped ice flow indicators show that ice movements within the study area included flow to the southeastward (youngest), southward and southwestward (oldest, Finck and Graves, 1987).



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Previous Geochemical Sampling Programs

Nova Scotia has been extensively covered by numerous regional geochemical surveys, including analysis of vegetation, till, stream sediments, stream waters, lake sediment and lake waters, and several of these surveys have included all or some of the current HRM study area.

Two regional till mapping and sampling programs have been completed over mainland Nova Scotia. One survey covered the Meguma Group metasediments while the other survey concentrated on the granitoid rocks of the South Mountain Batholith (SMB). The aerial distribution of the Meguma sample locations is similar to the distribution of the HRM till survey (Stea and Fowler, 1979, 1981). However, the Meguma survey was completed almost 25 years earlier than the current HRM study and analyzed the <2 µm fraction for approximately half the elements as the HRM survey. The SMB survey, however, overlaps the HRM study area boundary in the southwest corner (Boner *et al.*, 1990; Finck *et al.*, 1990a, 1990b). A regional bedrock mapping and sampling program was conducted during the same time as the regional SMB till program (Ham *et al.*, 1989, 1990).

Additional till geochemical surveys have also been completed by numerous exploration companies in their search for gold, tin, tungsten and other commodities. For example, Seabright Resources completed an extensive helicopter-assisted regional soil and till sampling program over the Meguma Group metasediments during 1986, 1987 and 1988 (Woodman *et al.*, 1994). Samples from their survey were collected within the extreme northwest corner of the HRM study area.

One of the most comprehensive regional geochemical studies of the current HRM study area was a 1977-1978 lake sediment bottom survey completed over southern mainland Nova Scotia (Bingley and Richardson, 1978). The main objective of this regional geochemical survey was to promote mineral exploration within the province.

Methodology

Introduction

During the 2001 and 2002 field seasons, a total of 25 sites were sampled at an average sampling density of approximately one sample site per 10 km^2 (Fig. 1). At some sites, additional soil and/or till samples representing field duplicates and profile samples were also collected. Most samples were collected from roadside exposures, and a few samples were collected from building excavations or along footpaths. Prior to the field sampling program, sample sites were carefully chosen to provide: (1) a broad aerial distribution of sample sites over the study area, (2) representative coverage of the major surficial units within the study area, (3) representative coverage of the major rockl units within the study area, and (4) easy access by taking advantage of pre-existing roads. In the field, sample sites were ultimately selected based on the availability of a fresh, undisturbed soil/till profile. Sample sites were immediately rejected if evidence of anthropogenic influences were observed (e.g. dumps, garbage, spillage, fences).

Sampling Methodology

B-horizon soil samples were collected by shovel and/or auger from an average sampling depth of about 30 cm. Approximately 500 g of soil were collected at each site and placed into a Kraft sample bag for geochemical analysis. All attempts were made to remove as much organic material as possible prior to placing the sample in the sample bag.

At each soil sample site, a C-horizon till sample was collected by shovel and/or auger from approximately 1 m depth. Again, approximately 500 g of till were collected at each site and placed into a Kraft sample bag for geochemical analysis, and all attempts were made to remove as much organic material as possible prior to placing the sample in the sample bag. Five of the till sites also had an additional till sample collected from an average sampling depth of 2 m. One site also had a

sample (HRM 2001-3010) collected from 3 m depth.

Samples collected during the 2001 field season were prefixed with HRM 2001, while samples collected during the 2002 field season were prefixed with HRM 2002. Soil samples were then assigned a number, for example the soil sample collected during 2001 at site 10 was designated HRM 2001-10. Till samples, on the other hand, were assigned a number based on their depth (1 m depth = 1000 series, 2 m depth = 2000 series and 3 m depth = 3000 series) and site number. For instance, the till sample collected at 1 m depth, site 10, was assigned HRM 2001-1010 while the sample at 2 m depth was assigned HRM 2001-2010 and the sample from 3 m depth was assigned HRM 2001-3010.

At each sample site, detailed field descriptions including observations on till type, colour and texture were recorded. Sample sites were geo-referenced to the Universal Transverse Mercator (UTM) grid (NAD 27) with a GARMIN GPS 12 using the averaging function. Each sample site was photographed for future reference.

Analytical Methodology

Till samples were forwarded in Kraft bags to DalTech Minerals Engineering Centre in Halifax, Nova Scotia, for drying and sieving. All soil and till samples were dried to a maximum drying temperature of 35° C.

Once completely dried, approximately 10 g of the <63 µm fraction were sieved and placed into a set of pre-labeled vials for Hg analysis. An additional 30 g of the <63 µm fraction were sieved and subsequently placed into a set of pre-labeled vials for multi-element geochemical analysis.

The vials containing 10 g of the <63 µm material were forwarded to ACME Analytical Laboratories of Vancouver, British Columbia. A subsample of approximately 1 to 2 g was analyzed for Hg by Cetac Cold Vapour Atomic Absorption (Cetac CV-AA) with a lower detection limit (LDL) of 1 ppb.

The larger 30 g vials were sent to ALS CHEMEX (formerly Bondar Clegg) in Val d'Or, Quebec, for geochemical analysis. An subsample of approximately 1 g was analyzed for multi-element geochemistry by Inductively Coupled Plasma/Atomic Emission Spectroscopy (ICP/AES) following an aqua regia digestion.

The third set of 50 g vials was retained by the author for archival purposes.

Quality Assurance/Quality Control (QA/QC)

Rigorous QA/QC protocols and procedures were implemented at all stages of the soil and till sampling program, including program planning, training, sample collection, sample preparation and sample analysis, to ensure the integrity of the data set. These procedures included: (1) collection of field duplicates, (2) insertion of preparation splits, (3) insertion of certified and in-house reference standards, and (4) inter-laboratory testing of random samples.

Results

Analytical results for concentration of elements (Hg-Ag-Cu-Pb-Zn-Mo-Ni-Co-Cd-Bi-As-Sb-Fe-Mn-Te-Ba-Cr-V-Sn-W-La-Al-Mg-Ca-Na-K-Sr-Y-Ga-Li-Nb-Sc-Ta-Ti-Zr-S) are pending.

Discussion

The opportunity to sample fresh soil and till profiles increases with urban and commercial growth as new roads and building foundations are created. Similarly, the opportunity to map fresh glacial ice flow indicators is also increased. However, this unique opportunity is often short lived. For example, fresh profiles are often lost as basement excavations are backfilled in rapidly expanding subdivisions. Similarly, fresh ice flow indicators on recently cleared bedrock are forever lost as shallow bedrock is often blasted for new road access or basement foundations. The stoss/lee feature shown in Figure 2 no longer exists because it was blasted in the summer of 2002 and a new building was erected.

Figure 2. Stoss/lee metasandstone outcrop of the Goldenville Formation. Ice flowed from left to right. This outcrop in the Atlantic Acres Industrial Park was blasted in the summer of 2002. A building now occupies the site.

During the initial planning phase, attempts were made to randomly sample all surficial units equally. However, the slate facies of the Beaver River till was the least sampled unit for several reasons. First, it's aerial distribution is limited when compared to the other facies of the Beaver River till (e.g. greywacke facies) and large areas mapped as slate till have been sterilized from sampling because they occur in the downtown commercial core of Halifax-Dartmouth.

In general, till in the study area is locally derived and is representative of the bedrock it was derived from. However, not all till sampled necessarily was derived from the local bedrock. The Lawrencetown till is characterized by a red clay-rich matrix derived from younger Carboniferous sedimentary rocks to the north and by foreign erratics originating as far away as the Cobequid Highlands (Lewis *et al.*, 1998). In a few sites where the drumlin facies of the Lawrencetown till was sampled, local greywacke cobbles and boulders were impregnated into the top of the drumlin resulting in a hybrid till facies (Lewis *et al.*, 1998).

In order to determine variance associated with the analysis of different size fractions, one sample site (HRM 2001-3a, 1003a and 2003a) also had the <180 µm fraction analyzed while a second sample site (HRM 2002-26a and 1026a) also had the <2000 µm fraction analyzed for Hg and multi-element geochemistry. An additional comparative study was also undertaken to determine variance associated with the use of a "total" multi-acid digestion of sample HRM 2002-26t.

Overall, analytical data are expected to show natural geologic variance related to different surficial and bedrock types, as well as variability associated with different size fractions, different acid digestions, different sample media and different sample depths. Therefore, when comparing analytical data, it is imperative to compare one set of results to previously reported results or established guidelines, that the comparisons are made for similar sample media, collected in a similar manner, and that samples were prepared and analyzed in a similar methodology.

In addition to natural geologic variance, the B-horizon soil has a high probability of being affected by anthropogenic effects, such as airborne pollution, even in areas considered remote. Anthropogenic effects, however, are limited to

approximately 40 cm depth, thus potentially affecting only the B-horizon soil samples collected for this survey (Henderson and McMartin, 1995).

Future geochemical studies within HRM should include a lithogeochemical study involving all bedrock types to characterize their geochemical signature. Additionally, an acid rock drainage study on the same survey should be completed in order to rank the potential of various rock types to produce ARD and map their spatial distribution for land-use planning.

Conclusions

Twenty-eight soil samples and 34 till samples were collected from within the Halifax Regional Municipality (HRM) at an average sampling density of approximately one sample site per 10 km^2. Strict QA/CQ protocols were an integral part of the sampling program.

Samples have been forwarded to several laboratories for multi-element geochemical analysis. Analytical results are pending and will serve as an historical geochemical baseline reference.

References

Bingley, J. M. and Richardson, G. G. 1978: Regional lake sediment surveys foe eastern mainland Nova Scotia; Nova Scotia Department of Mines and Energy, Open File Report 371, Scale 1:100 000.

Boner, F. J., Finck, P. W. and Graves, R. M. 1990: Trace element analysis of till (-230 mesh), South Mountain Batholith, N.T.S. sheets 11D/5, 12, 13, 21A/3, 4, 5, 6, 7, 9, 10, 11, 12, 14, 15, 16, 21H/2 and 20P/13; Nova Scotia Department of Mines and Energy, Open File Report 90-006, 108 p.

Environment Canada 1985: Metal contamination of lakes in the Waverley area. -- [Halifax] : Nova Scotia Department of the Environment; Environment Canada, Inland Waters Directorate. 6 p.

Finck, P. W., Boner, F. J. and Graves, R. M. 1990a: Heavy mineral till geochemistry (tin) of the eastern and central South Mountain Batholith; Nova Scotia Department of Mines and Energy, Open File Report 90-004, 21 p.

Finck, P. W., Boner, F. J. and Graves, R. M. 1990b: Heavy mineral till geochemistry (tin) of the western South Mountain Batholith; Nova Scotia Department of Mines and Energy, Open File Report 90-005, 41 p.

Finck, P. W. and Graves, R. M. 1987: Glacial geology of Halifax and Sambro; Nova Scotia Department of Mines and Energy, Map 87-2, Scale 1:50 000.

Ham, L. J., Marsh, S. W., Corey, M. C., Horne, R. J. and MacDonald, M. A. 1989: Lithogeochemistry of the eastern portion of the South Mountain Batholith, Nova Scotia; Nova Scotia Department of Mines and Energy, Open File Report 89-001, 62 p.

Ham, L. J., Corey, M. C., Horne, R. J. and MacDonald, M. A.1990: Lithogeochemistry of the western portion of the South Mountain Batholith, Nova Scotia; Nova Scotia Department of Mines and Energy, Open File Report 90-007, 31 p.

Haysom, S. J. 1994: The opaque mineralogy, petrology, and geochemistry of the Meguma Group metasediments, Rawdon area, Nova Scotia: unpublished B. Sc. thesis, St. Mary's University, Halifax, Nova Scotia, 45 p.

Henderson, P. J. and MacMartin, I. 1995: Mercury distribution in humus and surficial sediments, Flin Flon, Manitoba, Canada; Water, Air Soil Pollution v. 80, pp. 1043-1046.

Keppie, J. D. 2000: Geological Map of the Province of Nova Scotia; Nova Scotia Department of Natural Resources, Map ME 2001, Scale 1:500 000.

Lewis, C. F. M., Taylor, B. B., Stea, R. R., Fader, G. B. J., Horne, R. J., MacNeill, S. G. and Moore, J. G. 1998: Earth Science and Engineering: Urban

Development in the Metropolitan Halifax Region, *in* Urban Geology of Canadian Cities, eds. P. F. Karrow and O. L. White; Geological Association of Canada Special Paper 42, pp. 409-444.

MacDonald, M. A. and Horne, R. J. 1987: Geological Map of Halifax and Sambro; Nova Scotia Department of Mines and Energy, Map 87-6, Scale 1:50 000.

Prime, G. 2001: Overview of bedrock aggregate potential in the Halifax-Dartmouth Metropolitan area, Nova Scotia; Nova Scotia Department of Natural Resources, Economic Geology Series ME 2001-1, 74 p.

Stea, R .R. and Fowler, J. H. 1979: Pleistocene geology, eastern shore region, Nova Scotia (sheets 1-3), Scale 1:100 000, *in* Minor and Trace Element Variations in Wisconsinon Tills, Eastern Shore Region, Nova Scotia; Nova Scotia Department of Mines and Energy, Paper 79-4, 30 p.

Stea, R. R. and Fowler, J. H. 1981: Pleistocene geology and till geochemistry of central Nova Scotia, (sheet 4), 1980; Nova Scotia Department of Mines and Energy, Map 81-1, Scale 1:100 000.

Woodman, K. K., Duncan, D. R., Graves, R. M., Hudgins, A. B. and Rogers, P. J. 1994: Compilation of Seabright Resources Inc. Till and Soil Geochemical Data, Nova Scotia; Nova Scotia Department of Natural Resources, Open File Report 94-021, 238 p.

Eastern Shore Compilation Project

L. J. Ham

Work continued in 2002 on the Eastern Shore gold compilation project (Fig. 1). The first documented discovery of gold in the Eastern Shore area of Nova Scotia was made in 1858 at Mooseland. By the end of the 18th Century, gold had been discovered in many other places along the Eastern Shore, and numerous areas had been declared gold districts. Geological maps were produced early in the 19th Century by Fletcher and Faribault (e.g. 1886), and in 1929, Malcolm compiled known information on the gold districts into a classic memoir. Since the time of the first discoveries of gold, and particularly in the recent past, there has been considerable work undertaken by mineral exploration companies, prospectors, and geoscientists in universities and governments, including both the Nova Scotia Department of Natural Resources (NSDNR) and Geological Survey of Canada (GSC). There is a wealth of information dealing with various aspects of the gold districts on file with NSDNR, and also in private research files and internal company reports.

The original goals of this project were: (1) to compile existing information on the gold districts and surrounding areas of the Eastern Shore, (2) to incorporate relevant information onto a digital geological base map, (3) to produce databases and relevant cross-referencing links attached to the geological map, and (4) to write reports on selected

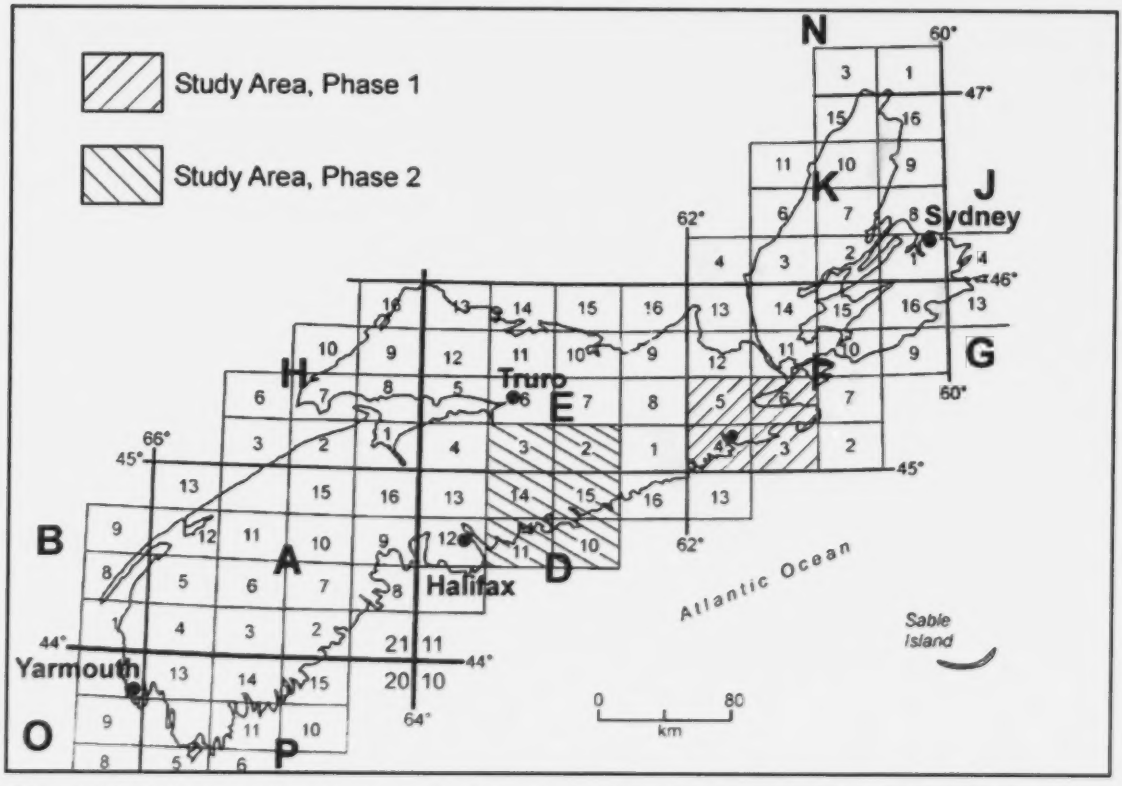

Figure 1. NTS index map of Nova Scotia showing the two areas, Phase 1 and Phase 2, which have been the focus of recent project activity.

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gold districts. Information available in assessment files, archived both as hard copy and microfiche, in the NSDNR library has been indexed over the years, and this information will also be incorporated through databases designed for this project.

As the project has progressed, and the information worked through, it became apparent that the original goals of the project were ambitious. Challenges associated with the capture and transfer of digital geological information have proven to be time-consuming. The project has been scaled back to reflect a more realistic goal: to capture and assure integrity of the geological information from original sources, most importantly the information of Faribault and Fletcher.

To this end, the most eastern portion of the map area (Phase 1; Fig. 1) will be released as an Open File Map in 2003 and work will continue on the second area (Phase 2; Fig. 1) for release by the end of 2004.

The initial work on the project, Phase 1, started in the easternmost portion of the project area, NTS map sheets 11F/03, 04, 05 and 06 (Fig. 1). The second area of the work, Phase 2, has involved gold districts closer to Halifax, NTS map sheets 11E/02, 03, 11D/10, 11, 14 and 15 (Fig. 1). Work on these areas has included site visits to former gold-producing districts, in addition to visiting numerous smaller showings and occurrences of various commodities on all NTS map sheets. Most of the former gold-producing sites were easily located and marked by abandoned mine shafts, old workings, adits or piles of waste rock and rubble.

Initial work from the mapping component of the project involved compiling base maps of the NTS map sheets using ArcView®. Geological information (outcrop locations, strike and dip information), particularly from Fletcher and Faribault's work, was digitized from available reference maps after a reference search. Work has involved using both the NSDNR Mineral Occurrence and Drillhole databases, and incorporating the location of all the mineral occurrences and drillholes within these databases on to digital bases. Using the newly compiled geological map of Nova Scotia (Keppie, 2000), the locations of mineral occurrence and drillholes were individually verified, and many subsequently re-located, by researching the assessment files where the original locations are reported. The corrected locations of drillholes have been entered into a database and are to be corrected at a later time in the master drillhole database files. The four NTS map areas of Phase 1 were displayed at a scale of 1:100 000 at the NSDNR Mining Matters conferences.

The next part of this project, Phase 2 (Fig. 1), involves the gold districts closer to Halifax; this "jump" over NTS map area 11D/16 and surrounding maps from Phase 1 will allow for digital bases to be constructed for this middle area. A major part of this project involves digitizing and using the geological information of Fletcher and Faribault and their original map series. This information is in progress for 11D/16, but is not available as yet.

Phase 2 involves twenty gold districts in the central portion of the Eastern Shore, some of which were former gold producers on a large scale, and includes the gold districts of Beaver Dam, Caribou, Chezzetcook, Clam Harbour, Cow Bay, Elmsdale, Fifteen Mile Stream, Gays River, Gold Lake, Killag, Lake Catcha, Lake Charlotte, Lawrencetown, Mooseland, Moose River, Oldham, Ragged Falls, Sheet Harbour, Tangier, and Upper Stewiacke. The project results will follow the same format as for Phase 1 (Ham, 2001). Digital maps will be produced, incorporating all the known and available geology, and databases will be constructed and linked to the maps. Individual deposit reports will also be written.

The project areas are underlain by metasedimentary rocks of the Goldenville and Halifax formations, with Goldenville Formation rocks deformed into east-west, doubly plunging anticlines and synclines, with strata of the Halifax Formation resting primarily in synclinal troughs. Observation at most gold districts shows that most veins are either interbedded and occur mainly in beds of slate interstratified within Goldenville Formation quartzite, or are discordant and crosscut

both slate and meta-greywacke. These veins occur at various depths throughout the formation and have been drilled to depths >700 m. Primary folds and secondary structures, particularly in the gold districts, are complex. The more important geological features include domed anticlines and numerous local and regional faults, generally trending northwest. The location of veins and associated gold deposits associated with these anticlinal structures has been the focus of numerous researchers ever since these deposits were first discovered nearly 150 years ago. Local faults, found in all districts, are related mainly to late-stage, brittle deformation throughout the region.

As was done for Phase 1, individual gold deposits of Phase 2 are discussed below. The individual gold districts that have been the current focus of research, in order of production, are: Caribou, Oldham, Tangier, Moose River, Fifteen Mile Stream, Lake Catcha (Chezzetcook), Mooseland, Killag, Gays River, Cow Bay, Beaver Dam, Lawrencetown, Lake Charlotte, Clam Harbour, Upper Stewiacke, Gold Lake, Sheet Harbour, Elmsdale, and Ragged Falls. Brief descriptions of each of these districts are included below, and many of these descriptions have been simplified from Malcolm (1929) and other information available in NSDNR assessment files. All production figures are taken from Bates (1987). Locations for the individual districts are found on Figure 2.

Caribou: The Caribou gold district lies on a dome formed by the plunging of an anticline to the east and west; this same anticline occurs at Cochrane Hill. Folding and subsequent erosion have exposed the upper parts of the Goldenville Formation in the form of an elongated ellipse. Localized faulting is common. Both interbedded and cross-cutting veins are found in this district; interbedded veins are found in the Goldenville Formation interstratified with meta-greywacke. The cross-cutting veins transect stratigraphy at a small angle and are found in the lower beds of the Halifax Formation, near the Halifax-Goldenville contact. Veins most extensively worked are the Caffre, Lake, Dixon, Burner and McDonald. Rich ore occurs in many veins, and the Lake vein proved one of the richest in the Nova Scotia gold fields. Work on this district began in 1867 and by 1869 two crushers and numerous stamp mills were in operation. Extensive underground work was undertaken well into the 1900s, and total production was 91,335.8 troy ounces, making Caribou one of the larger producing gold districts in Nova Scotia.

Oldham: Oldham, one of the oldest and deepest gold districts in the province, has been worked extensively over the years since the discovery of gold-bearing quartz boulders in 1861. This district produced 85,177.5 troy ounces. A domed, tightly folded and extensively faulted, easterly-plunging anticline hosts interbedded gold-bearing veins and few cross veins. The most productive part of district is the eastern end, which has undergone the most faulting. A fault follows the axis of the anticline and radiating from the dome to the southeast are a series of right-hand faults with displacements of over 30 m. Most of this faulting is speculated to post-date vein development. The more important interbedded veins from this district are the Dunbrack, Sterling, Boston-Oldham, North and South Wallace and Donaldson, others worked profitably are the Barrel, Blue, Frankfort, Ohio, Ritchie, and Wallace; important cross veins are the Baker, which occupies a fault plane, and the Britannia. In the early days of Oldham's development, most work was open-cut and included extensive trenching.

Tangier: Gold was discovered at Tangier in 1860 and total historic production for the Tangier area was 26,286.5 troy ounces. The Goldenville Formation is exposed in the east-west Tangier-Harrigan Cove anticline, the most southerly anticline exposed on the eastern mainland. The fold plunges in both directions at a slight angle, forming a long, narrow dome. The rocks have been disturbed by two important series of faults striking northwest and southeast. Tangier is unique to all the gold districts in hosting a lamprophyre dyke (~12 m wide) in the gold district, perpendicular to strata and oriented north-south. Gold-bearing veins are interbedded and most historical work has been limited to those found on the south limb of the fold. Some of the more important leads are Big South, Little South, Kent or Nugget, Learn, Lake, Forrest, Dunbrack or Twin, and Wallace. Recent

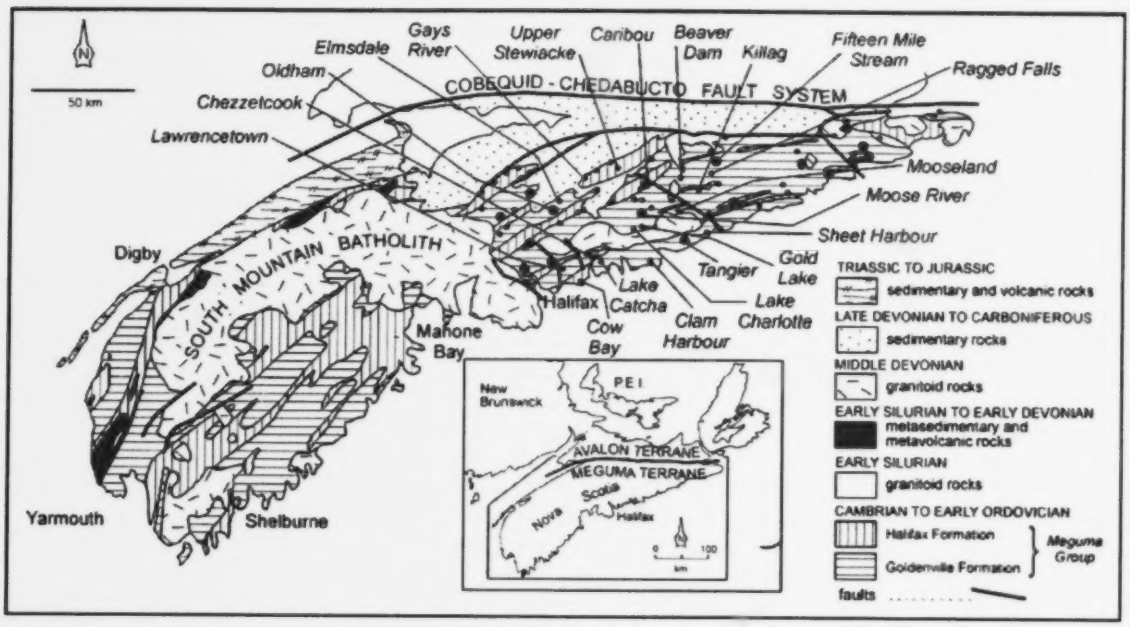

Figure 2. Simplified geological map of the Meguma Terrane of Nova Scotia (modified after Keppie, 2000) showing the former gold districts and locations of specific districts discussed in the text.

exploration and development work was undertaken at Tangier (Atkinson, 1997) by Tangier Limited Partnership and Tangier Mining Incorporated. A mining permit was applied for, but the work did not continue. When the mine closed down, NSDNR acquired much of the original information from this work. Another aspect of this compilation project will catalogue this original mine information.

Moose River: Gold was discovered in Moose River in 1866 and the district produced 25,917.2 troy ounces. This gold district is located in a wide zone of interbedded slate, meta-siltstone and meta-greywacke of the Goldenville Formation. The Moose River district has the greatest thickness of Goldenville exposed (Faribault estimated the thickness to be ~5 km) in the province. Another unique feature of this district is that the ore-bearing veins are confined to a belt (~500 m wide) of schistose slate with little meta-greywacke, different from the typical Halifax Formation slate, which is exposed to the north of the mine workings. The structure of the rocks suggests two anticlines converging in a westerly direction, and the development of subordinate folds with subsequent east-west faulting. With minor exception, all veins worked in this district are the interbedded type with connected angular veins. The most important veins are northerly dipping and occur on the crown of the northern anticline. Some of the more important leads in this district are Copper, Little North, Little South, Big North, Serpent, Kaulback, and Comstock. historical work was done on what was called the Touquoy mine which is host to disseminated gold in artillite/meta-siltstone.

Fifteen Mile Stream: This gold district, one of the oldest in the province, occurs on a branch of the East River, Sheet Harbour area (see Sheet Harbour and Ragged Falls districts also). Interbedded veins lie within intercalated slate and meta-quartzite layers, and the most auriferous veins occur on an anticline in the north of the district (Moose River-Fifteen Mile Stream Anticline), the same northern anticline that passes through the Moose River gold district. At Fifteen Mile Stream, this anticline is domed and consists of three minor anticlinal folds. Leads worked on the northerly anticlines include the Old Egerton, McPhee, McGilligan, Island, Serpent, McLean, Walton-Doran and Jackson. In the southern part of the district, leads worked are the Orient, Nonpareil, Mother Seigel and Harvey.

These leads exhibit high-grade rolls and swells produced by zones of crumpling and numerous angulars within the gold-bearing quartz veins. Production from this district was 21,291.6 troy ounces.

Lake Catcha: This deposit was commonly also referred to as Chezzetcook. Gold was discovered in this area in 1865 but not developed until 1881. Production at Lake Catcha extracted a total of 17,961 troy ounces of gold, and Chezzetcook produced 5,528.1 troy ounces. Goldenville Formation rocks are exposed in an easterly-trending, domed anticline with variable, but steeply dipping limbs. Numerous faults cross the gold district. Most of the veins lie in bedding planes; however, two cross-cutting veins (the Copper and Cogswell) are auriferous, and both lie on the northern limb of the anticline. The cross-cutting veins follow bedding planes in slate, cross-over quartzite at a steep angle, then resume along a slate bedding plane; this type of veining is also found in other districts. Gold is generally concentrated in shoots; in the Coleman vein, gold is found in three shoots lying in undulations below one another and dipping at low angles. High concentrations of gold and iron sulphides are found in certain slate beds.

Mooseland: The first discovery of auriferous quartz in Nova Scotia was in the Mooseland gold district in 1858. This original gold district produced 3,865.1 troy ounces of gold, although additional production may also be included with reported production for the Tangier district. The Goldenville Formation is exposed in a closely folded anticline, which plunges gently to the east and west, forming an elongate dome. The main axis of the fold curves and numerous veins are found on the convex side of the axis. Several lines of faults occur in the eastern end of the district, with displacement along the faults. Granite of the Musquodoboit Batholith lies directly to the southwest of this district, and a few veins have been traced to the granite. Veins are stratified and most of the veins worked are confined to the southern limb of the anticline, with the zone of enrichment lying close to the axis. Among the most important veins are the Bismarck, Irving, Little North, Specimen, Cummings and Furnace.

Killag: Gold was described from the area in the 1860s, but the source of rich gold-bearing quartz boulders was not found until 1889. Production ultimately yielded 3,583.6 troy ounces of gold. The Goldenville Formation is exposed here in a southeast-trending anticline. In contrast to other gold districts, there has been very little faulting reported. Veins are interbedded, have been worked on both limbs of the anticline, and are found in greatest concentration at the apex of the fold. The leads that have been worked most extensively are the Flat lead and the Stuart lead.

Gays River: This district received only minor attention as a gold district, producing a total of 2,268.2 troy ounces, but it received considerable interest from the geological setting. Gold, believed to be derived from metasedimentary Meguma Group rocks, occurs in coarse conglomerate at the base of the Lower Carboniferous Horton Group, and it thus is a good example of a fossil placer deposit. This conglomerate is exposed at the base of the a ridge of slates of the metasedimentary rocks. A series of auriferous quartz veins is found along an anticline at the top of the ridge to the south of the conglomerate.

Cow Bay: Gold was discovered in this area in 1895 and total production was 1,483.5 troy ounces. Cross-cutting veins, also referred to as fissures, are important at Cow Bay and form the principal auriferous deposits. The contact between the Halifax and Goldenville formations runs through this district and numerous north-south veins cross the contact. A belt of grey argillaceous meta-greywacke, with pockets of extensive pyrrhotite, occurs at the contact, and auriferous veins are richest where they cut the pyrrhotite-bearing quartzite.

Beaver Dam: Total production from this gold district was relatively small, being 966.7 troy ounces in total. Although discovered in 1868, work was limited following the discovery, and production is documented from 1889 to 1949. The Goldenville Formation is folded in an overturned anticline running northeast and southwest. Veins are both interbedded and discordant, and all lie on the southern limb of the anticline.

Lawrencetown: Gold was first officially discovered here in 1861, though it had been recognized several years earlier. With the discovery of gold at Tangier, the gold at Lawrencetown was then given credence. By 1862, forty distinct veins were opened, but little work was undertaken until shafts were sunk in 1868. Although a limited amount of gold (866.7 troy ounces) was taken from this property, the auriferous zone is wide (over a mile long and nearly half a mile wide), as two anticlines converge from the east and approach each other in this area. Auriferous veins lie in bedding planes, the most important being Wadlow, Middle, Bennett, Werner, Nickie, Belt and Vance. One main fault trends southeast and other subordinate faults were discovered during mining.

Lake Charlotte: This deposit is the only gold district of southern Nova Scotia that lies totally within a syncline. It is situated near the northern contact of the Musquodoboit Batholith and is overprinted by contact metamorphic minerals. Although only limited gold was recovered (77.5 troy ounces), grades in the several veins worked are high (~1 oz. Au/t).

Clam Harbour: This gold district received little interest; several veins were opened and several shafts were sunk, producing a total of 53.9 troy ounces. Goldenville Formation meta-quartzite is folded and exposed in two east-west anticlines that converge in the west of the district. At the eastern end of the district, strata between the two main anticlines is crumpled into two minor folds and minor faulting occurred. Gold-bearing veins are both interbedded and cross-cutting, with the former the richer veins and confined to slate beds within the meta-quartzite. Cross-cutting veins are thought to be feeders to the interbedded veins, and gold levels are highest at the intersection of the two vein types.

South Branch or Upper Stewiacke: Gold at this district occurs in both interbedded and crossing veins within rocks of the Halifax Formation; the cross veins are the richer veins. The meta-sedimentary rocks have been tightly folded into an anticline. Auriferous boulders found along the anticlineal trace led to the initial discovery in this district. Total production from this district was 43.9 troy ounces.

Gold Lake: This gold district is located 6 km south of Moose River gold district and limited gold was extracted (38.6 troy ounces). It lies on the Killag-Goldenville antcline and gold is confined to interbedded veins.

Sheet Harbour: Several veins were prospected on the East and West Rivers in the Sheet Harbour area, producing 3.9 troy ounces of gold. These auriferous veins occur on the south limb of a subordinate fold on the south limb of the Salmon River anticline.

Elmsdale: Limited work was done in this district, with a production total of 1.4 troy ounces. Auriferous veins are found within the meta-quartizite of the Goldenville Formation.

Ragged Falls: Interbedded veins were prospected close to the Sheet Harbour district, on Twelvemile Stream branching off the East River. These veins occur in meta-quartzite of the Goldenville Formation, on the south limb of the Moose River-Beaver Dam anticline.

References

Atkinson, P. H. 1997: Tangier Gold Deposit [Blueberry Hill Mine], Halifax County, Nova Scotia; Report on an application for a mining permit; Property Report ME 1997-2, Library, Halifax, Nova Scotia Department of Natural Resources.

Bates, J. L. E. 1987: Gold in Nova Scotia; Nova Scotia Department of Mines and Energy, Information Series No. 13.

Fletcher, H. and Faribault, E. R. 1886: Province of Nova Scotia, Guysborough County; map to illustrate Geological Survey of Canada, Part A, Annual Report, v. 11; maps 25, 26, 27, 29 and 30, scale 1:63 360.

Ham, L. J. 2001: Eastern Shore Compilation Project, *in* Minerals and Energy Branch Report of Activities 2000, ed. D. R. MacDonald; Nova Scotia Department of Natural Resources, Report ME 2001-1, p. 23-28.

Keppie, J. D. (compiler) 2000: Geological Map of the Province of Nova Scotia; Nova Scotia Department of Natural Resources, Minerals and Energy Branch, Map ME 2000-1, scale 1:500 000.

Malcolm, W. 1929: The gold fields of Nova Scotia; Geological Survey of Canada, Memoir 156 (reprinted in 1976 as Geological Survey of Canada Memoir 385).

U-Pb Age Data for Belle Côte Road Orthogneiss, Taylors Barren Pluton and Bothan Brook Pluton, Southern Cape Breton Highlands (NTS 11K/07, 11K/10, 11K/11): Igneous Ages and Constraints on the Age of Host Units, and Deformational History

R. J. Horne, G. Dunning[1] and R. Jamieson[2]

Introduction

The geology of the Cape Breton Highlands is complex and has stimulated considerable debate, primarily over the regional-scale tectonic architecture of the area. Barr and Raeside (1989) divided Cape Breton Island into four pre-Carboniferous tectono-stratigraphic terranes: Mira, Bras d'Or, Aspy and Blair River (Fig. 1). Keppie (1990) and Keppie *et al.* (1990) included the whole of Cape Breton Island in the Avalon Terrane, inferring correlation of units across the terranes of Barr and Raeside (1989), including Precambrian metasedimentary rocks (George River Group and equivalents) and a Cambrian-Ordovician overstep sequence. Lynch (1996) proposed that the distribution of units reflects a folded nappe consisting of higher grade units overlying lower grade units. It is apparent that at the heart of much of the debate is the correlation (or not) of rock units based on lithology and age, and the interpreted relationship between rock units. It is equally apparent that, despite the amount of documented information, the range of interpretations for the region is based not on what is known, but rather what is unknown.

The objective of this report is to publish the results of U-Pb dating of three samples from plutonic units in the south-central Cape Breton Highlands, all in the Aspy Terrane of Barr and Raeside (1989). In addition to providing ages for plutonic activity, these data help constrain the age of meta-stratified units intruded by the plutonic units and the age of deformational events for which relations with the dated units are known. This report is essentially an appendix to the map report on the geology of the south-central Cape Breton Highlands by Horne (1995), to which the reader is referred for more detailed information and discussion on the geology of the area. Coupled with established field relations, the age data reported here provide further understanding of the geological history of the area. In addition, the data have some consequences for regional correlations, and therefore tectonostratigraphic interpretations. Results of the dating reported here have been referred to in Horne (1995) and, more recently, in Price *et al.* (1999), where the significance of these ages has been discussed. A summary of the more important implications is presented below.

Setting

The study area is situated in the Aspy Terrane of Barr and Raeside (1989), which consists of Ordovician or older metamorphic (sedimentary and igneous) rocks of variable grade intruded by Ordovician, Silurian, and Devonian plutons (Fig. 1). Contacts between metamorphic units within the Aspy Terrane are commonly obscured by deformation and metamorphism, and post-metamorphic faults, thus clouding the relationships between units. This has led to various interpretations, particularly regarding the relationship between the higher- and lower-grade units. Currie (1987) considered the high-grade gneissic rocks (e.g. Pleasant Bay complex) to

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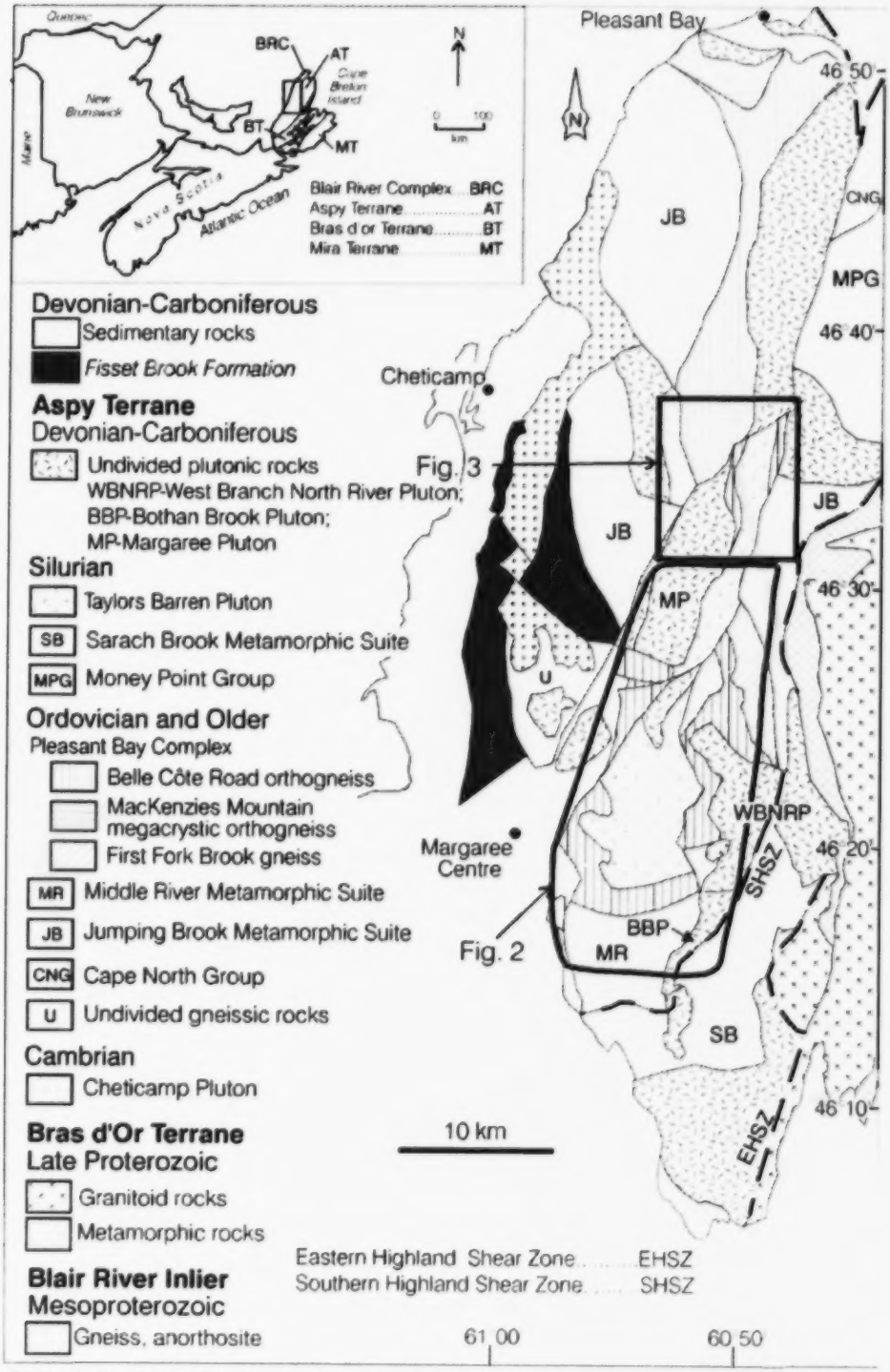


Figure 1. Simplified geology map of western Cape Breton Highlands (modified from Price *et al.*, 1999) showing the location of the study area.

represent basement to lower grade rocks (e.g. Jumping Brook metamorphic suite) in the Cheticamp area. Plint and Jamieson (1989), Jamieson *et al.* (1987) and Barr and Jamieson (1991) considered the higher grade rocks to be high-grade equivalents of the lower grade units. Lynch (1996) suggested that the high-grade rocks represent the erosional remnant of a folded nappe emplaced over the lower grade rocks.

As mentioned above, the dated samples are from units within the map area of Horne (1995) and will be discussed with respect to the field relationships established there (Fig. 2). The sample of Belle Côte Road orthogneiss was collected north of the map area of Horne (1995); however, this unit has been correlated with the Belle Côte Road orthogneiss in this map area by Price *et al.* (1999). The dated rock units belong to a coherent "assemblage" that has shared a long geological history, which predated intrusion of the oldest dated unit, the Belle Côte Road orthogneiss (Horne, 1995). The Sarach Brook metamorphic suite and Kathy Road diorite (Bras d'Or terrane) are separated from this assemblage within the study area by faults (Fig. 2). General field relationships constrain the following geological history for the area (Fig. 2; see Horne, 1995; Price *et al.* 1999; MacDonald, 1996). (1) Deposition of protoliths of the meta-stratified units, including the First Forks Brook gneiss, Jumping Brook metamorphic suite and Middle River Metamorphic suite. (2) Regional metamorphism and deformation recorded by an S_1 foliation preserved as inclusion trails within garnet porproblasts. (3) Syn-tectonic intrusion of the Belle Côte Road orthogneiss, with formation of the principal gneissic (metamorphic layering) fabric (S_2). (4) Syn-tectonic intrusion of the Taylors Barren pluton with development of a weak to well-developed foliation (S_2) (augen fabric) parallel to the gneissic fabric in the Belle Côte Road orthogneiss and older units. (5) Regional-scale folding of the S_2 foliation to produce a map-scale fold. (6) Intrusion of unfoliated plutons (Bothan Brook, West Branch North River, Peters Brook). (7) Development of regional-scale, mylonitic shear zones (Southern Highlands and Coinneach Brook shear zones) which deform unfoliated plutons. (8) Possible folding of shear zones. (9) Brittle faulting, including deformation of shear zones.

Sample Locations, Description and Age Data

Samples were selected to provide maximum information over the range of geologic history of the area, with the three units including undeformed (Bothan Brook pluton), moderately deformed (Taylors Barren pluton) and strongly deformed (Belle Côte Road orthogneiss) plutonic units. Relative age relations had been established between units (Horne, 1995; Price *et al.*, 1999; MacDonald 1996) as well as deformational events (Horne, 1995). Therefore, in addition to providing the crystallization age of the plutons, the ages constrain the time of deformational events (e.g. Table 3, Horne, 1995).

The U-Pb dating reported was carried out at the geochronology laboratories of Memorial University, using laboratory procedures similar to those described in Dubé *et al.* (1996). The three dated samples represent igneous units, and the objective was to establish crystallization ages for these units.

Belle Côte Road Orthogneiss

The analysed sample of the Belle Côte Road orthogneiss is the same sample analyzed by Jamieson *et al.* (1986; i.e., their Belle Côte Road orthogneiss sample). The data of Jamieson *et al.* (1986) showed evidence of an older component of radiogenic lead and the best estimate for the crystallization age was given as 433 +20/-10 Ma (Jamieson *et al.*, 1986). The sample was re-analysed in hope of establishing a more precise age of crystallization.

The Belle Côte Road orthogneiss consists of well foliated granodioritic to tonalitic orthogneiss; however, minor amphibolite and paragneiss are common (Horne, 1995; Price *et al.* 1999; Marcotte 1987; Jamieson *et al.* 1987). A description of the sample, which was collected along the Belle Côte Road (Fig. 3), is provided in Jamieson *et al.* (1986), with a summary given here. The sample consists of "pink- to white-weathering gneisic tonalite to granodiorite with diffuse compositional layering defined by alternate biotite-rich and feldspar-rich layers". Mineralogy includes oligoclase, quartz,

microcline and biotite with accessory oxide minerals, apatite, zircon, garnet and tourmaline, and secondary chlorite (Jamieson *et al.*, 1986). This description is similar to the field and petrographic descriptions of Horne (1995), Price *et al.* (1999) and Marcotte (1986).

Three fractions of zircon gave $^{207}Pb/^{206}Pb$ ages of 442 (Z1), 442 (Z2) and 447 (Z3) Ma (Table 1). Fraction Z2 is concordant and a line through 442 and 0 incorporates fraction Z1 (Fig. 4). Fraction Z3 is below this line and is interpreted to reflect a minor component of inherited Pb, which was evident in the previous analysis of this sample reported by Jamieson *et al.* (1986). A minor component of inherited zircon is not unexpected considering the common occurrence of paragneiss xenoliths within this unit, for example, an enclave of First Forks Brook east of the sample location (Fig. 3). From these data, the best estimate for a crystallization age is 442±3Ma.

Taylors Barren Pluton

The Taylors Barren pluton consists of a variably foliated, pink-red, augen monzogranite-syenogranite consisting of K-feldspar, plagioclase, quartz, biotite (mainly altered to chlorite) and accessory opaque minerals, apatite, titanite and zircon (Horne, 1995; MacDonald, 1996). The dated sample of Taylors Barren pluton was collected on a branch of Nile Brook just south of Fielding Road (Fig. 5). The sample consists of a weakly foliated augen granite (compare Figs. 10b of Horne, 1995), which was selected to limit any potential effect that deformation may have had on resetting or disturbing the crystallization age for the sample. The sample was free of xenoliths, as is generally the case with the Taylors Barren pluton.

The sample yielded high quality zircon and two fractions of euhedral grains, which were strongly abraded, are concordant (Fig. 4, Table 1). The age of crystallization based on all Pb/Pb and U/Pb ages (429 to 431 Ma, Table 1) is 430±2Ma.

Bothan Brook Pluton

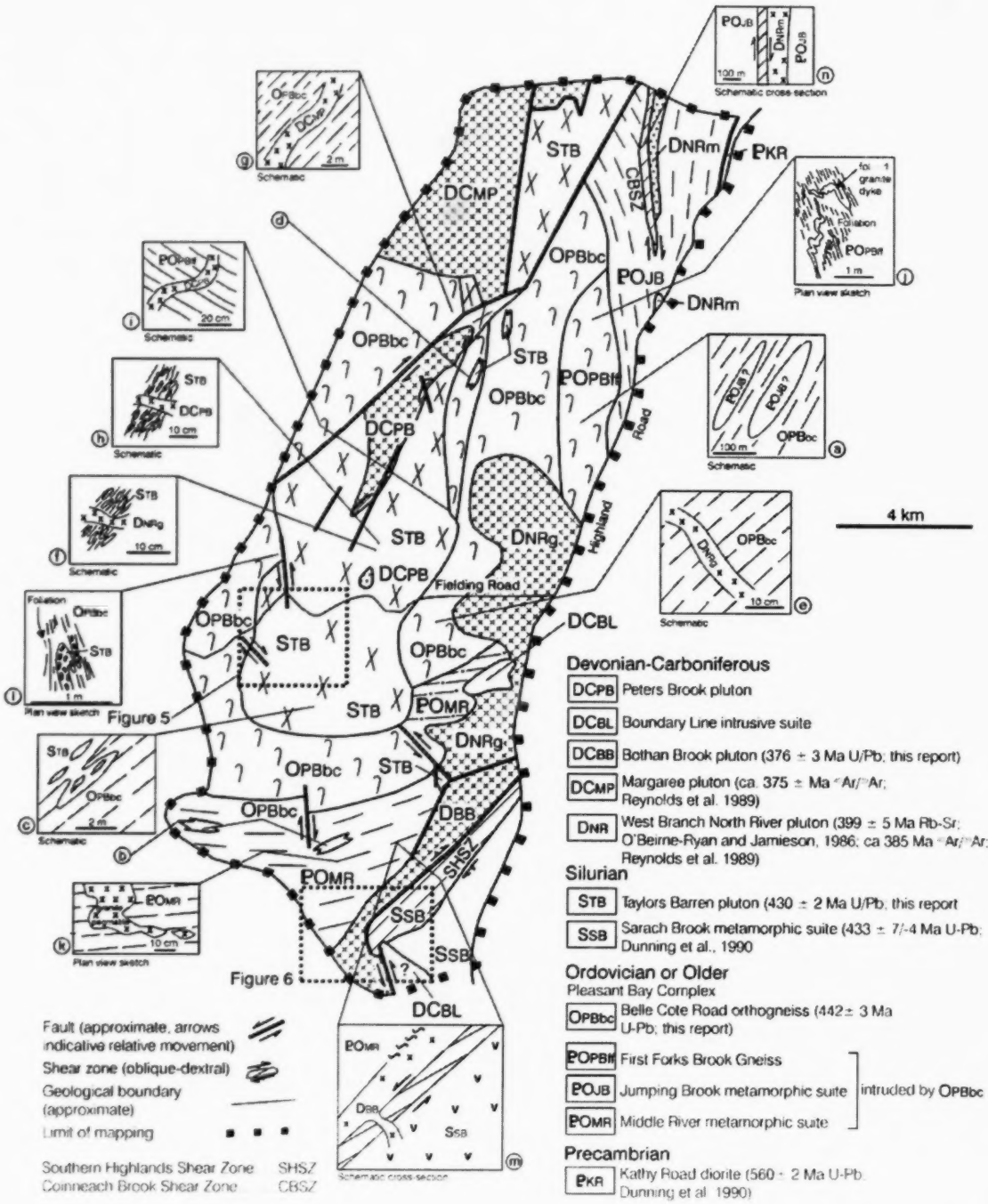
The Bothan Brook pluton consists of medium-grained, equigranular to slightly megacrystic pink granite (eg. Fig. 13b of Horne, 1995), consisting of K-feldspar, plagioclase, chlorite (after biotite?) quartz and accessory muscovite, sphene, epidote and opaque minerals. This unit is relatively free of xenoliths. The sample analysed is from along Bothan Brook (Fig. 6).

The sample yielded a large amount of zircon as euhedral prisms and needles. Three fractions of zircon analysed are 2.5-5% discordant, defining a line with an upper intercept of 376 Ma and a lower intercept of 0 Ma (Fig. 4; Table 1), for an interpreted crystallization age of 376±3 Ma.

Discussion

The age data are interpreted to provide crystallization ages for the respective plutons, recording a plutonic history from Late Ordovician-Early Silurian to Late Devonian. Established field relationships of the dated units place constraints on the ages of other units and

Figure 2 (facing page): Simplified geology map of the study area with inset diagrams illustrating observed field relationships. Trend of map ornamentations parallel the principal tectonic fabric (S_2). Locations of Figures 3 and 4 are indicated. Inset diagrams: (a) Paragneiss of the First Forks Brook gneiss possibly representing enclaves of Jumping Brook metamorphic suite in the Belle Côte Road orthogneiss; (b) A satellite intrusion of Belle Côte Road orthogneiss in the Middle River metamorphic suite; (c) Contact between the Belle Côte Road orthogneiss and Taylors Barren pluton, with xenoliths of the former in the latter; (d) satellite intrusions of Taylors Barren pluton within the Pleasant Bay complex; (e) Dyke of granodiorite of the West Branch North River pluton cutting the Belle Côte Road orthogneiss; (f) Dyke of granodiorite of the West Branch North River pluton cutting the Taylors Barren pluton; (g) Dyke of Margaree pluton cutting the Belle Côte Road orthogneiss; (h) Dyke of Peters Brook pluton cutting the Taylors Barren pluton; (i) Dyke of Peters Brook pluton cutting the First Forks Brook gneiss;(j) Folded granite dyke cutting the First Forks Brook gneiss; (k) Folded dyke cutting the Middle River metamorphic suite; (l) Folded dyke of Taylors Barren pluton within the Belle Côte Road orthogneiss; (m) Mylonitic contact between the Bothan Brook pluton and Sarach Brok metamorphic suite; (n) mylonitic contact between the Jumping Brook metamorphic suite and the West Branch North River pluton (*after Horne, 1995*).


DCMP
STB
DNRm
PKR
CBSZ
OPBbc
POJB
DCPB
POPBff
DNRg
DCBL
DBB
POMR
SSB
SHSZ
Fielding Road
Highland Road
4 km
Figure 5
Figure 6
Devonian-Carboniferous
DCPB Peters Brook pluton
DCBL Boundary Line intrusive suite
DCBB Bothan Brook pluton (376 ± 3 Ma U/Pb; this report)
DCMP Margaree pluton (ca. 375 ± Ma ⁴⁰Ar/³⁹Ar; Reynolds et al. 1989)
DNR West Branch North River pluton (399 ± 5 Ma Rb-Sr; O'Beirne-Ryan and Jamieson, 1986; ca 385 Ma ⁴⁰Ar/³⁹Ar; Reynolds et al. 1989)
Silurian
STB Taylors Barren pluton (430 ± 2 Ma U/Pb; this report
SSB Sarach Brook metamorphic suite (433 ± 7/-4 Ma U-Pb; Dunning et al., 1990
Ordovician or Older
Pleasant Bay Complex
OPBbc Belle Cote Road orthogneiss (442± 3 Ma U-Pb; this report)
POPBff First Forks Brook Gneiss
POJB Jumping Brook metamorphic suite
POMR Middle River metamorphic suite
intruded by OPBbc
Precambrian
PKR Kathy Road diorite (560 ± 2 Ma U-Pb; Dunning et al. 1990)
Fault (approximate, arrows indicative relative movement)
Shear zone (oblique-dextral)
Geological boundary (approximate)
Limit of mapping
Southern Highlands Shear Zone SHSZ
Coinneach Brook Shear Zone CBSZ

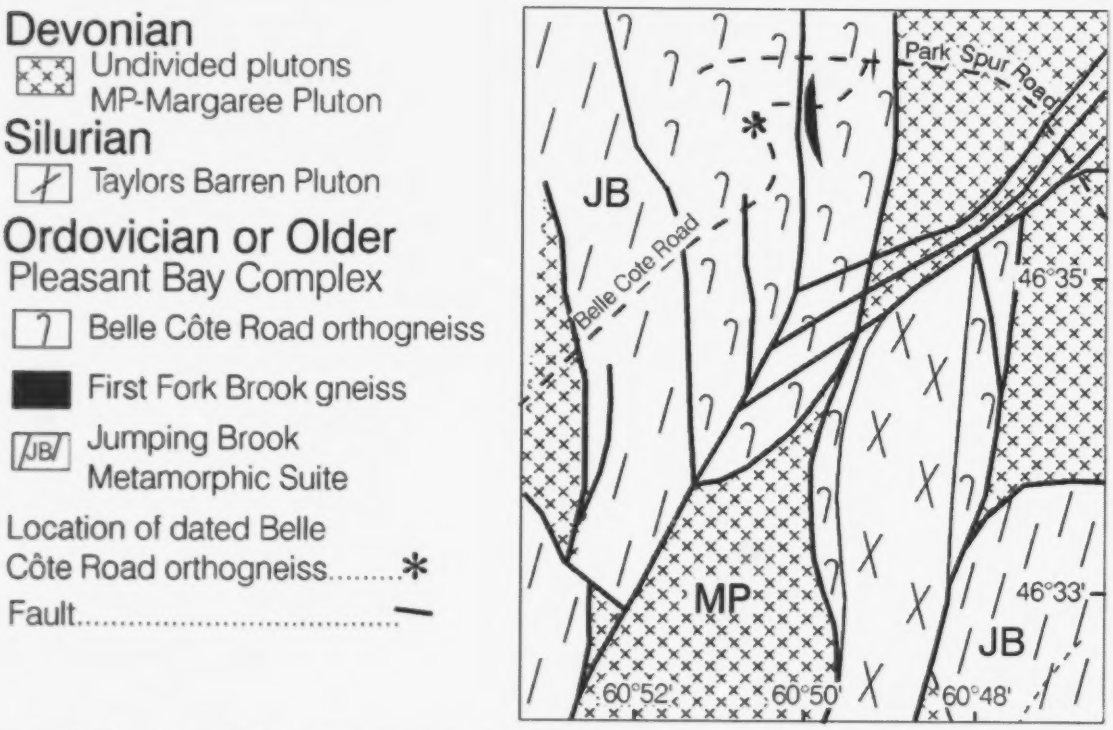


Figure 3. Map showing the location and setting of the Belle Côte Road othogneiss sample used for U-Pb dating; area of map indicated on Fig. 1 (*map modified from Price et al. 1999*).

structural features, providing for a well constrained understanding of the geological history of the area. The reader is referred to Horne (1995) for a full discussion; however, an overview of the significance of the ages and a summary of the geologic history is given here. In addition, the ages provide new constraints on the ages of older units (First Forks Brook gneiss, Middle River and Jumping Brook metamorphic suites) and constrain the time of shearing along the SHSZ, which have consequences with respect to regional correlation of units and thus the regional architecture.

Geological History

Belle Côte Road Orthogneiss

The Belle Côte Road orthogneiss forms part of the Pleasant Bay Complex, which in the study area includes the First Forks Brook gneiss. Within the study area, the Belle Côte Road orthogneiss is interpreted to intrude the First Forks Brook gneiss, Middle River metamorphic suite and Jumping Brook metamorphic suite (Horne, 1995; Price *et al.*, 1999; Jamieson *et al.*, 1987), and therefore constrains the age of these units as pre 442±3 Ma (Late Ordovician-Early Silurian). The meta-stratified units intruded by the Belle Côte Road orthogneiss preserve an earlier tectonic fabric (S_1) within garnet porphroblasts which predated the principal foliation (S_2) affecting the Belle Côte Road orthogneiss and the units which it intruded (Horne, 1995). Therefore, an episode of regional metamorphism and deformation predating intrusion of the Belle Côte Road orthogneiss must be accounted for when constraining the depositional ages of these units; these units could be considerably older and of various ages.

Taylors Barren Pluton

The 430±2 Ma age for the Taylors Barren pluton establishes the existence of Early Silurian plutonism within the Aspy Terrane. The foliation within Taylors Barren pluton parallels the principal

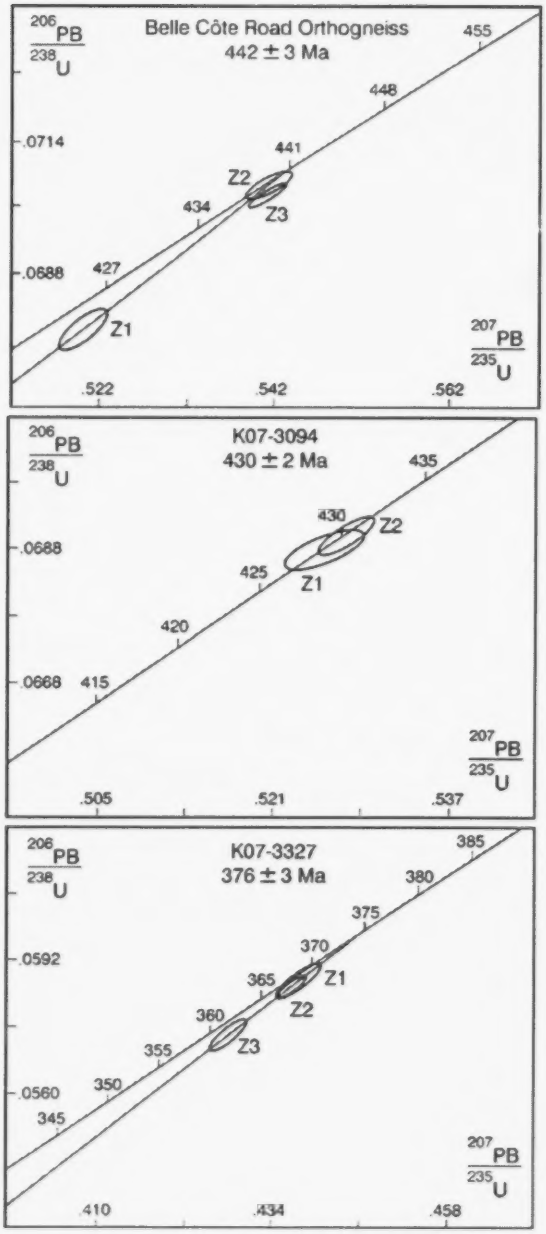


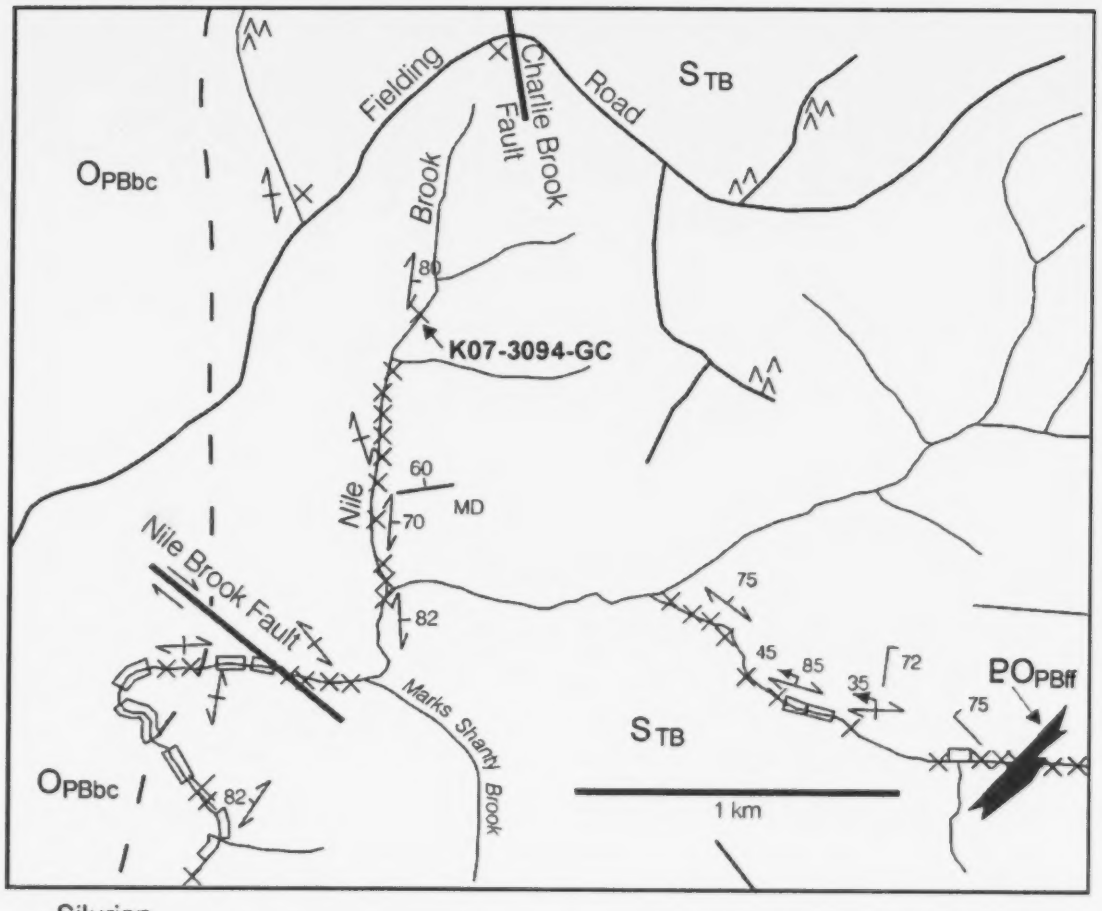
Figure 4. U-Pb concordia diagram for zircon from (a) Belle Côte Road orthogneiss, (b) Taylors Barren pluton and (c) the Bothan Brook pluton; see Table 1 for isotopic data.

fabric in the Belle Côte Road orthogneiss, best demonstrated by folded dykes of Taylors Barren pluton cutting the Belle Côte Road orthogneiss (Fig 2, insets c, l; Fig. 11b, Horne 1995), where the principal foliation is axial planar to the folds. This observation indicates a protracted history for the development of the principal fabric (S_2) which overlaps emplacement of the Taylors Barren pluton, implying syn-tectonic emplacement of this pluton.

The principal fabric in the Taylors Barren pluton and older units is folded into a regional-scale fold (Fig. 2; Horne, 1995, Price *et al.*, 1999). Unfoliated plutons, including the West Branch North River and Peters Brook plutons, cut the Taylors Barren pluton and arguably postdate regional folding of the principal foliation, thus constraining the age of regional folding to between 430 Ma (emplacement of the Taylors Barren pluton) and emplacement of the West Branch North River and Peters Brook plutons (Devonian; see below).

Bothan Brook Pluton

The Bothan Book pluton was previously mapped as a separate pluton (e.g. O'Beirne-Ryan and Jamieson, 1986), but generally included as part of the western lobe of the West Branch North River pluton, with which it is contiguous (Fig. 1), on compilation maps (Barr *et al.*, 1992; Lynch *et al.*, 1995; Keppie, 2000). Clear field relationships between the Bothan Brook pluton and West Branch North River plutons have not been documented. The 376 Ma age determined for the Bothan Brook pluton suggests that it is not part of the West Branch North River pluton, which is likely significantly older, based on an Rb/Sr whole rock isochron (399±5 Ma, O'Beirne-Ryan and Jamieson, 1986) and $^{40}Ar/^{39}Ar$ biotite (?) (ca. 385; Reynolds *et al.*, 1989) age data. The Bothan Brook pluton is deformed along its eastern margin by the Southern Highlands shear zone (SHSZ; Fig. 13c of Horne, 1995), thereby constraining the shearing to post-376 Ma.



Silurian

S_{TB} Taylors Barren pluton

Ordovician or Older

O_{PBbc} Belle Côte Road orthogneiss

PO_{PBff} First Forks Brook gneiss

Probable outcrop (felsenmeer)

Outcrop

Stream section

Foliation; inclined, vertical

Mylonitic foliation

Lineation

Joint

Figure 5. Map showing the location and setting of the sample of Taylors Barren Pluton sample (K07-3094) used for U-Pb dating. Location of map indicated on Fig. 2 (map after Horne, 1995).

Table 1. Table of U-Pb isotopic data for zircon fractions from the Belle Cote Road orthogneiss, Taylors Barren pluton and the Bothan Brook pluton. Abbreviations: rad-radiogenic; pg-picograms; N-nonmagnetic, M-magnetic (number following N and M is refers to the degree of tilt of the Franz separator); Clr-clear; euh-euhedral; abr-abraded; lg-large)

		Concentration (ppm)		Measured		Corrected Atomic Ratios							Age (Ma)		
Fraction	Weight (mg)	U	Pb rad	Total Common Pb (pg)	206 Pb / 204 Pb	208Pb / 206Pb	206Pb / 238U	±	207Pb / 235U	±	207Pb / 206Pb	±	206Pb / 238U	207Pb / 235U	207Pb / 206Pb
Belle Côte Road Orthogneiss															
Z1 clr euh prisms	0.099	480	32.8	14	14852	0.1180	0.06769	32	0.5202	22	0.05574	16	422	425	442
Z2 mO clr euh abr	0.106	316	22.7	64	2442	0.1292	0.07047	20	0.5415	22	0.05573	14	439	439	442
Z3 clr euh abr - crack	0.106	779	54.3	49	7772	0.0976	0.07028	20	0.5413	18	0.05586	6	438	439	447
K07-3094 Taylor's Barrens															
Z1 nmO clr lg prism abr	0.081	262	19.0	69	1407	0.1746	0.06878	24	0.5257	30	0.05544	24	429	429	430
Z2 nmO clr prisms abr	0.121	349	25.5	62	3092	0.1753	0.06899	24	0.5277	20	0.05547	12	430	430	431
K07-3327 Bothan Brook															
Z1 MO clr euh abr	0.047	501	31.5	9	10547	0.1910	0.05868	36	0.4378	24	0.05412	14	368	369	376
Z2 mO clr abr - small	0.108	632	39.9	32	8124	0.1982	0.05852	22	0.4367	18	0.05412	8	367	368	376
Z3 clr needles	0.041	720	44.1	33	3428	0.1871	0.05735	30	0.4280	22	0.05413	14	359	362	376

Notes: All data produced using standard procedures, ion exchange chemistry, thermal ionization mass spectrometry, accepted decay constants for U from Jaffey *et al.* 1977.

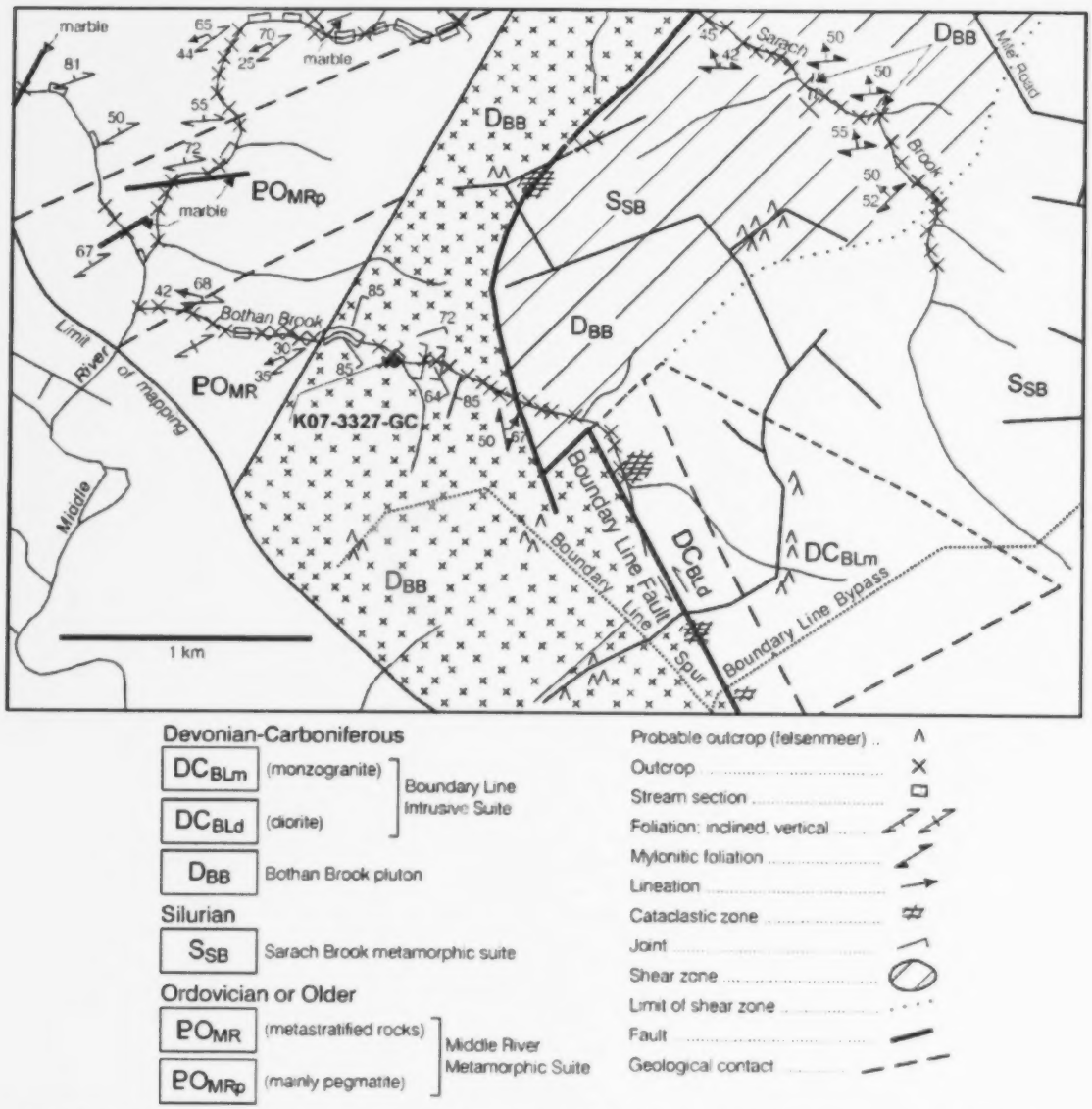


Figure 6. Map showing the location and setting of the sample of Bothan Brook pluton (K07-3327) used for U-Pb dating. Location of map indicated on Fig. 2 (*map after Horne, 1995*).

Summary

The above discussions illustrate the significance of the new age data when coupled with well-established field relationships between units and deformational features. Following is a summary of the geological history of the study area resulting from the new age data and established field relations.

Ordovician or older

(a) Deposition of the First Forks Brook, Jumping Brook and Middle River units.
(b) Regional metamorphism with development of S_1 foliation.

Late Ordovician-Early Silurian

(a) Syn-tectonic intrusion of the Belle Côte Road orthogneiss **(442±3Ma)**, development of regional S_2 foliation.

Early Silurian

(a) Syn-tectonic intrusion of Taylors Barren pluton **(430±Ma)**, continued development of regional S_2 foliation.
(b) regional folding of regional S_2 foliation.

Mid-Late Devonian

(a) intrusion of unfoliated plutons, including West Branch North River pluton, Peters Brook pluton, Bothan Brook pluton **(376±3 Ma)**, Boundary Line intrusive suite.
(b) Ductile shearing - Southern Highlands Shear Zone.
(c) Development of brittle faults.

Regional Significance

As discussed by Price *et al.* (1999), the interpreted Ordovician or older age for the First Forks Brook gneiss, Middle River metamorphic suite and Jumping Brook metamorphic suite, which are intruded by the Belle Côte Road orthogneiss, demonstrates that these units are not correlative with Silurian units such as the Sarach Brook metamorphic suite (433+7/-4 Ma U-Pb; Dunning *et al.*, 1990) and the Money Point metamorphic suite (427.5±4 Ma; Keppie *et al.*, 1991), as earlier thought (e.g., Barr and Jamieson, 1991). The age of the Belle Côte Road orthogneiss and its intrusive relationship with these older units would, however, not support the idea that the Pleasant Bay complex represents basement to units such as the Jumping Brook metamorphic suite as suggested by Currie (1987). Importantly, the higher grade Ordovician or older units (First Forks Brook gneiss, Middle River metamorphic suite and Jumping Brook metamorphic suite) are separated from the younger units (Sarach Brook metamorphic suite and Money Point metamorphic suite) by significant shear zones (eg. SHSZ, Fig. 2), thus concealing the original relationship between these rock units.

The age of the Bothan Brook pluton constrains a post 376 Ma age for the Southern Highlands shear zone (SHSZ), which clearly deforms this pluton (Fig. 13c of Horne, 1995). The SHSZ is an important part of the postulated thrust system responsible for emplacement of the Cabot nappe of Lynch (1996), and the Late Devonian or younger age of deformation constained by the Bothan Brook pluton is somewhat younger the age of thrusting (377-380 Ma) proposed by Lynch (1996).

Acknowledgments

Steve King assisted RJH with collection of samples of the Bothan Brook and Taylors Barren pluton. Many thanks to Dan Kontak who provided RJH with discussion and insight into the U-Pb data. We thank Sandra Barr for providing digital versions of Figures 1 and 3 (originally published in Price *et al.*, 1999), and for helpful comments.

References

Barr, S. M., Jamieson, R. A. and Raeside, R. P. 1992: Geology, Northern Cape Breton Island, Nova Scotia; Geological Survey of Canada, Map 1752A, scale 1:100 000.

Barr, S. M. and Rayside, R. P. 1989: Tectonostratigraphic terranes in Cape Breton Island, Nova Scotia: implications for the configuration of the northern Appalachian Orogen; Geology, v. 17, p. 822-825.

Dubé, B., Dunning, G. R., LauziPre, K. and Roddick, J. C. 1996: New insights into the Appalachian Orogen from geology and geochronology along the Cape Ray fault zone, southwest Newfoundland; Geological Society of America Bulletin, v. 108, p. 101-116.

Dunning, G. R., Barr, S. M., Raeside, R. P. and Jamieson, R. A. 1990: U-Pb zircon, titanite monazite ages in the Bras d'Or and Aspy terranes of Cape Breton Island, Nova Scotia: implications for magmatic and metamorphic history; Geological Society of America Bulletin, v. 102, p. 322-330.

Horne, R. J. 1995: Geology of the south-central Cape Breton Highlands (Parts of NTS sheets 11K/07 and 11K/10), Inverness and Victoria Counties, Nova Scotia; Nova Scotia Department of

Natural Resources, Mineral and Energy Branch Paper 95-2, 61 p.

Jamieson, R. A., van Breemen, O., Sullivan, R. W. and Currie, K. L. 1986: The age of igneous and metamorphic events in the western Cape Breton Highlands, Nova Scotia; Canadian Journal of Earth Sciences, v. 23, p. 1891-1901.

Jamieson, R. A., Tallman, P., Marcotte, J. A., Plint, H. E. and Connors, K. A. 1987: Geology of the west-central Cape Breton Highlands, Nova Scotia; Geological Survey of Canada Paper 87-13.

Keppie, J. D. 2000: Geological Map of the Province of Nova Scotia; Nova Scotia Department of Natural Resources, Minerals and Energy Branch, Map ME 2000-1, scale 1:500 000.

Lynch, G. 1996. Tectonic burial, thrust emplacement, and extensional exhumation of the Cabot nappe in the Appalachian hinterland of Cape Breton Island, Canada; Tectonics, v. 15, p. 94-105.

Lynch, G., Barr, S. M., Houlahan, T. and Giles, P. 1995: Geological compilation, Cape Breton Island, Nova Scotia; Geological Survey of Canada, Open File Map 3159, scale 1:250 000.

MacDonald, C. A. 1996: Petrography, geochemistry, and structure of the Taylors Barren pluton, Cape Breton Island, Nova Scotia; Unpublished BSc thesis, Acadia University, Wolfville, Nova Scotia.

Marcotte, J-A. 1987: Regional mapping and petrographic study of a Silurian gneissic complex, Belle Côte Road, Cape Breton, Nova Scotia; Unpublished BSc thesis, Dalhousie University, Halifax, Nova Scotia.

Price, J. R., Barr, S. M., Raeside, R. P. and Reynolds, P. H. 1999: Petrology, tectonic setting, and $^{40}Ar/^{39}Ar$ (hornblende) dating of the Late Ordovician - Early Sillurian Belle Côte Road orthogneiss, western Cape Breton Highlands, Nova Scotia; Atlantic Geology, v. 35, p. 1-17.

Reynolds, P. H., Jamieson, R. A., Barr, S. M. and Raeside, R. P. 1989: An $^{40}Ar/^{39}Ar$ study of the Cape Breton Highlands, Nova Scotia: thermal histories and tectonic implications; Canadian Journal of Earth Sciences, v. 26, p. 2081-2091.

The Coxheath Plutonic-Volcanic Belt (NTS 11K/01): A Linked Porphyry-Epithermal Mineralized System of Precambrian Age

D. J. Kontak, J. DeWolfe[1] and P. W. Finck

Introduction

Porphyry-type mineral deposits typically occur in Mesozoic and younger, calc-alkaline to alkaline volcanic-plutonic terranes formed predominantly at convergent plate margins (Sillitoe, 1976; Mitchell and Garson, 1981; Titley and Beane, 1981). These deposits are important repositories for Cu, Mo and Au, and account for a significant proportion of the total global resources. Presently the Cu-Au deposit types are amongst the most sought-after exploration targets given their large size, precious-metal endowment and cost-efficient open pit mining technique. The high-level nature of these mineralized systems, generally within the volcanic pile or the underlying, coeval plutonic environment (Sillitoe, 1973; Titley and Beane, 1981), is susceptible to rapid denudation in active orogenic belts, hence the likelihood of preservation in ancient terranes is considered poor, although rarely reported (Gustafson and Titley, 1978). Thus it is somewhat anomalous that inferred porphyry-type mineral occurrences older than Mesozoic age are reported in a number of locations in the northern Appalachians. More than ten porphyry-type systems have been reported in eastern Canada, including Gaspe Copper in eastern Quebec, Benjamin River in New Brunswick, and Coxheath in Nova Scotia (Hollister *et al.*, 1974; Kirkham and Soregaroli, 1975). The Coxheath deposit is even more anomalous given the ca. 620 Ma age for the host rock (Barr *et al.*, 1996).

In the present paper the results of previous work on the Coxheath Cu-Mo-Au deposit (Kontak *et al.*, 2000; DeWolfe, 2000) are integrated with recent investigations of previously known pyrophyllite occurrences in the northern part of the Coxheath Group volcanic rocks. The presence of pyrophyllite in volcanic rocks is common in high-sulphidization, epithermal base- and precious-metal deposits (White and Hedenquist, 1995), which themselves may be linked to an underlying porphyry system (Hedenquist et al., 1998). Thus, this paper explores the possibility that these spatially associated pyrophyllite occurrences are in fact the high-level manifestation of a genetically linked porphyry system at depth. The present distribution of the spatially and temporally related plutonic-volcanic rocks of the Coxheath belt suggest that this mineralized environment may represent a section through a porphyry environment, perhaps analogous to the large Yerington, Nevada, porphyry system exposed in a 6 km section because of post-emplacement tilting (Dilles and Einaudi, 1992).

Previous Work

Copper was first reported in the Coxheath Hills area in 1875 by Hugh Fletcher of the Geological Survey of Canada in his report on the Sydney coal fields. Subsequently high-grade copper was found in a shear zone along Copper Creek (Mine Zone) near where the number 2 shaft was put down. Most of the mine development occurred from 1881-1889 when five shafts were sunk and trenches and adits cut, and again in 1928-1930 when the shafts and drifts were further developed and a new zone explored (Mountain Zone). Most of the ore (to 3-10% Cu) extracted from the mine came from four sub-parallel shear zones known as the B, C, D and LW veins. The number 2 shaft was dewatered in 1947 and two levels (260, 340) were partially sampled by the Nova Scotia Department of Mines in order to assess its potential. A resource of

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ca. 100,000 tons of 3% Cu was estimated to occur from the 340 level to surface. Later development and exploration delineated several other low-grade copper ore zones, and in 1964 Mariner Mines Ltd. discovered molybdenum in granitoid rocks of the Central Zone. This latter discovery changed the concept of the deposit from that of a high-grade, small-tonnage copper prospect to that of a potentially large-tonnage, lower-grade porphyry system (Chatterjee and Oldale, 1980). Moreover, the work of Mariner Mines and others over the past few decades has firmly established the potential for a large-tonnage, low-grade porphyry deposit with representative multi-metre intervals carrying 0.5 to 1.5% Cu with 1-5 g/t Au and molybdenum intercepts of about 1% Mo over 2 m and 0.3% over 16 m (Chatterjee and Oldale, 1980; L. Jensen, personal communication, 2001).

The mineralized area has been examined by several workers, all of whom have noted the similarities with porphyry-style mineralization (Hollister *et al.*, 1974; Kirkham and Soregaroli, 1975; Chatterjee and Oldale, 1980; Lynch and Ortega, 1997; DeWolfe, 2000). Most recently, Ortega and Lynch (1994a, b) mapped out a large, zoned alteration pattern in the plutonic-volcanic rocks that is similar to the alteration sequence present in typical porphyry systems (Lowell and Guilbert, 1970). Lynch and Ortega (1997) discussed the nature of the ore assemblage, alteration and nature of the tourmaline alteration in the Coxheath deposit and drew analogues with large porphyry-epithermal systems where similar alteration occurs. Furthermore, these authors also recognized the strong similarities of the Coxheath system to Au-bearing porphyries, noting the disseminated nature of the Au, the association with Cu, presence of sodic and calcic alteration in the mineralized environment, and pervasive propylitic alteration (Sillitoe, 1993).

Regional Geological Setting

The Coxheath plutonic-volcanic belt (CPVB) occurs in eastern Cape Breton Island and is the westernmost of several Late Precambrian (i.e. Hadrynian) volcanic-plutonic belts that together form part of the Avalon Terrane of the Canadian Appalachians. These belts, from the Atlantic coastline in the east to the Bras d'Or Lakes in the west, are the Coastal Belt (570 Ma), Stirling Belt (680 Ma), Sporting Mountain Belt (620 Ma), East Bay Hills Belt (620 Ma), and Coxheath Belt (620 Ma). Based on the petrological features of the igneous rock suites, these belts are considered to represent the remnants of once extensive continental margin plutonic-volcanic arcs that formed above ancient, westward-dipping, subduction zones (e.g. Keppie and Dostal, 1991). Thus, these belts may be considered ancient analogues of the Andean-type continental margin tectonics where numerous porphyry deposits are located. The rocks form basement blocks that define prominent topographic highs surrounded by younger Cambrian to Carboniferous sedimentary rocks. Within these rocks are variable amounts of polymetallic mineralization that correlate in terms of metal endowment and style with porphyry (e.g. Coxheath) and massive sulphide (VHMS; Stirling) types of deposits.

The Coxheath Group of the CPVB underlies the Coxheath Hills and Spruce Brook areas on the north side of East Bay and is divided into three lithological units of basaltic, andesitic and rhyolitic composition. Each unit contains both flows and fragmental rocks, but epiclastic sedimentary rocks are rare. The volcanic rocks were intruded by dioritic to granitic rocks. The rocks have been metamorphosed to greenschist or sub-greenschist facies and have a weak, northeast-trending fabric with steep dips. Poles to primary layering in the volcanic rocks suggest folding about a southwest-plunging axis. The volcanic and plutonic rocks are overlain unconformably by Cambrian to Carboniferous sedimentary rocks.

Geological Features of the Coxheath Deposit

The geology of the two relevant areas of this study, namely the Coxheath Cu-Mo-Au mineralized system and the pyrophyllite-altered felsic volcanic rocks (Fig. 1), are described separately below. Subsequently the two areas are integrated into a genetic model which links them as part of a porphyry, high-sulphidization epithermal system. A more complete description of the Coxheath area is

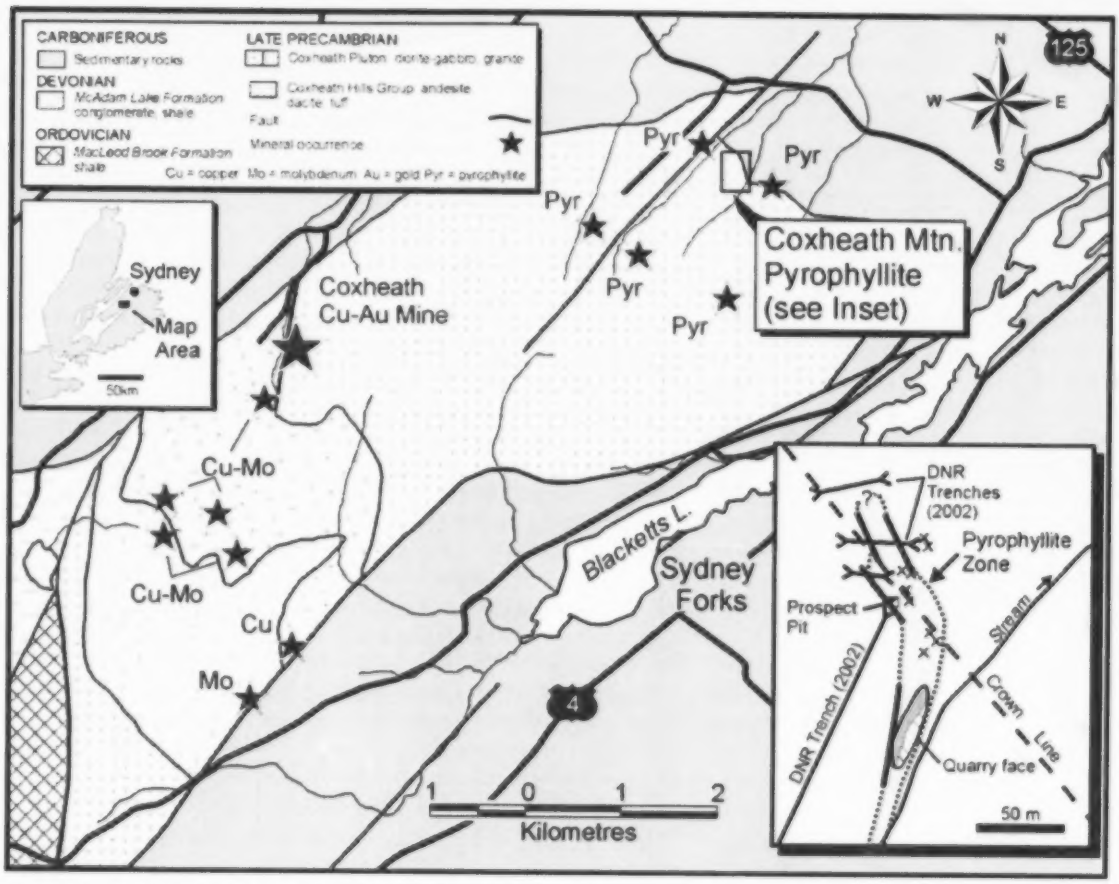


Figure 1. Regional geological setting of the Coxheath area showing the location of the Coxheath deposit and related mineralized zones, and the areas of pyrophyllite mineralization. Inset box is enlargement of the area of trenching done by NSDNR in fall of 2002.

in preparation (Kontak and Dewolfe, in prep.) and what follows is a brief description of a more comprehensive database.

Petrology of the Plutonic and Volcanic Rocks of the Coxheath Deposit Area

The Coxheath deposit occurs within a medium- to fine-grained hornblende diorite pluton that intrudes a volcanic carapace of basalt and basaltic andesite. More felsic rocks occur distally from the Coxheath deposit area toward the northeast. The medium-grained phase can be followed upward, that is toward higher exposed levels topographically, into a much finer-grained equivalent. In one place in the southwest end of the Coxheath quarry[1], the diorite is chilled over 20 cm against volcanic rock and xenoliths of the volcanic rock are seen in the diorite. Inclusions of andesite within the diorite were also noted in drill core from different zones of the deposit.

[1]Quarry here refers to a relatively recent excavation site (1990s) where diorite was extracted and crushed for use as aggregate material. The quarry has no significance to the previous mining of the area, but it does provide excellent exposure of the diorite host rock.

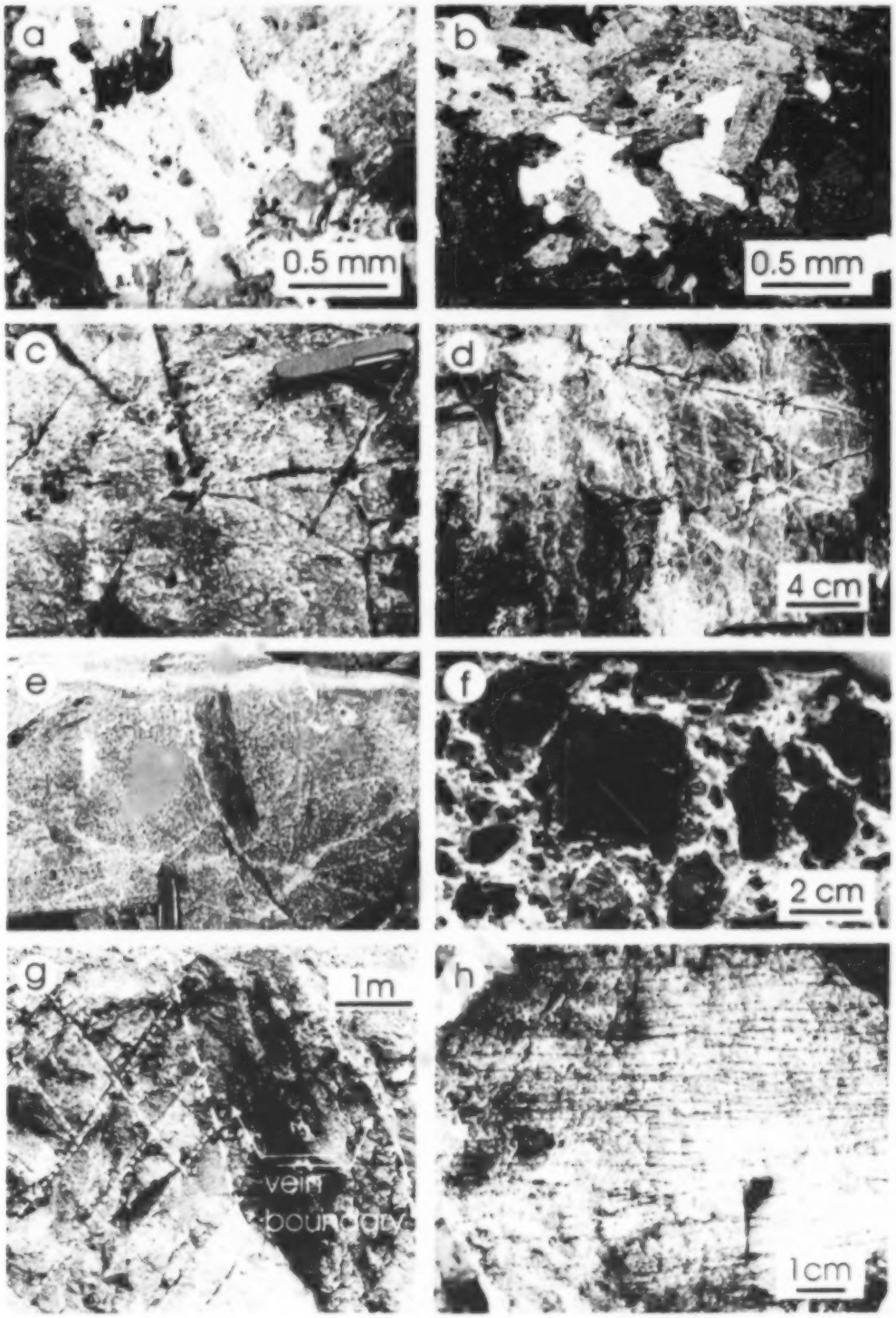
The diorite is well exposed in a quarried wall in the Coxheath Zone (Fig. 1) and scattered outcrops towards the Deep Pit area, which form the basis for the following observations. The diorite is massive and its texture varies from seriate to hypidiomorphic granular with ≤5% amphibole and ≤30% plagioclase phenocrysts. A well developed set of conjugate fractures occurs (see below). Mineralogically the diorite is dominated by calcic plagioclase with normal zoning of An_{30-58}, amphibole of edenite-magnesiohornblende composition, and accessory apatite, titantite, and unmixed Fe-Ti oxides. At least two stages of magmatic amphibole crystallization occurred, based on textural relationships, and later overgrowths related to orthomagmatic to hydrothermal activity occur (DeWolfe, 2000). Rare examples of altered, remnant pyroxene occur in the diorite and some biotite, of olive-green color, is present in the diorite of the Deep Pit Zone. In addition, two unusual petrographic features are noted about the diorite throughout the area. (1) The first is the occurrence of small cavity-like areas (≤2-3 mm) that are filled with subhedral to euhedral quartz, albite and flame perthite (Fig. 2a). The albite in these areas may contain abundant disseminated needles of apatite. The origin of this feature remains unresolved, as it may represent a late magmatic or early orthomagmatic phenomenon. (2) The second feature is the presence of anhedral to suhedral quartz coring plagioclase grains without signs of hydrothermal alteration (Fig. 2b). Although there is an increase of these features in mineralized areas, it is not obvious if they are an alteration-related phenomenon. Commonly, the diorite has fine-grained disseminations of white mica within the plagioclase, and chloritic alteration of the amphibole and biotite.

The volcanic rocks vary from massive, aphanitic to variably porphyritic with ≤20% plagioclase phenocrysts of 2-7 cm length (Fig. 2c). The variable proportion of phenocrysts suggests multiple flow units, but these have not been distinguished in the field. In thin section, the volcanics are dominated by plagioclase laths, chlorite and disseminated opaques.

Petrology of Dyke Rocks in the Coxheath Area

Dyke rocks include both mafic and felsic types, and have been observed both in outcrop and drill core and within the diorite and volcanics. Several mafic dykes of <1 m width, steeply dipping and with northeast to easterly strikes, occur in the quarry area, but wider dykes (to 5 m) have been observed elsewhere in the area (Chatterjee and Oldale, 1980). The mafic dykes look like volcanic rocks when fine grained, have ≤5% plagioclase phenocrysts (≤3-5 cm length), and may have chilled margins (1-2 cm). In thin section the dykes have a trachytic texture, are dominated by plagioclase laths (60-70%) and chlorite (20-25%), with minor carbonate and Fe-Ti oxides, and its altered equivalent leucoxene. The aplitic dykes occur in the Deep Pit grid area, are flat lying, 2-10 cm thick, have a granitic mineralogy and a saccharoidal texture. The mafic and felsic dyke rocks have minor propyllitic and carbonate alteration and no mineralization was observed within or cutting them. The timing of dyke emplacement is poorly constrained. Those with alteration similar to that related to the mineralization are presumed to be part of the Coxheath plutonic-volcanic suite, but where such alteration is not present the age is unconstrained.

Figure 2 (facing page). (a) Photomicrograph of diorite showing miarolitic-like cavity fill with anhedral alkali feldspar. Note the euhedral terminations of the plagioclase projecting toward the cavity, reflecting growth into a once open space. (b) Plagioclase with fine-grained white mica alteration and subhedral, graphic-like textural intergrowth of quartz. This feature occurs throughout the diorite, but is more prevalent near mineralized areas. (c) Outcrop photo of plagioclase phryic andesite. Note the conjugate fracture pattern (i.e. cooling joints) and pen knife for scale (8 cm). (d, e) Propylitic alteration focused along fractures in andesite (d) and diorite (e). Note the conjugate orientation of fractures in these units (also see Fig. 3b). Pen knife for scale is ca. 8 cm. (f) Slab of sulphide-bearing (i.e. chalcopyrite), quartz-cemented, monolithic volcanic breccia. Note the angular nature of the fragments and local jigsaw texture, and the fact that this is a matrix-supported breccia (i.e., must have been hydrostatically supported). (g) Outcrop of stockwork vein at west end of quarry face in Coxheath Zone. The margin of the vein sytem, as delineated by area of intense fracturing, alteration and veining, is indicated by the dashed lines. Note that the vein is discordant to the orientation of conjugate fractures, indicated by the dashed lines, in the diorite host to the left of the vein. (h) Outcrop photo of sheeted vein system in the Deep Pit area. Note the high density (i.e. 100-300/metre) of fracture-controlled veins, which contain sulphides.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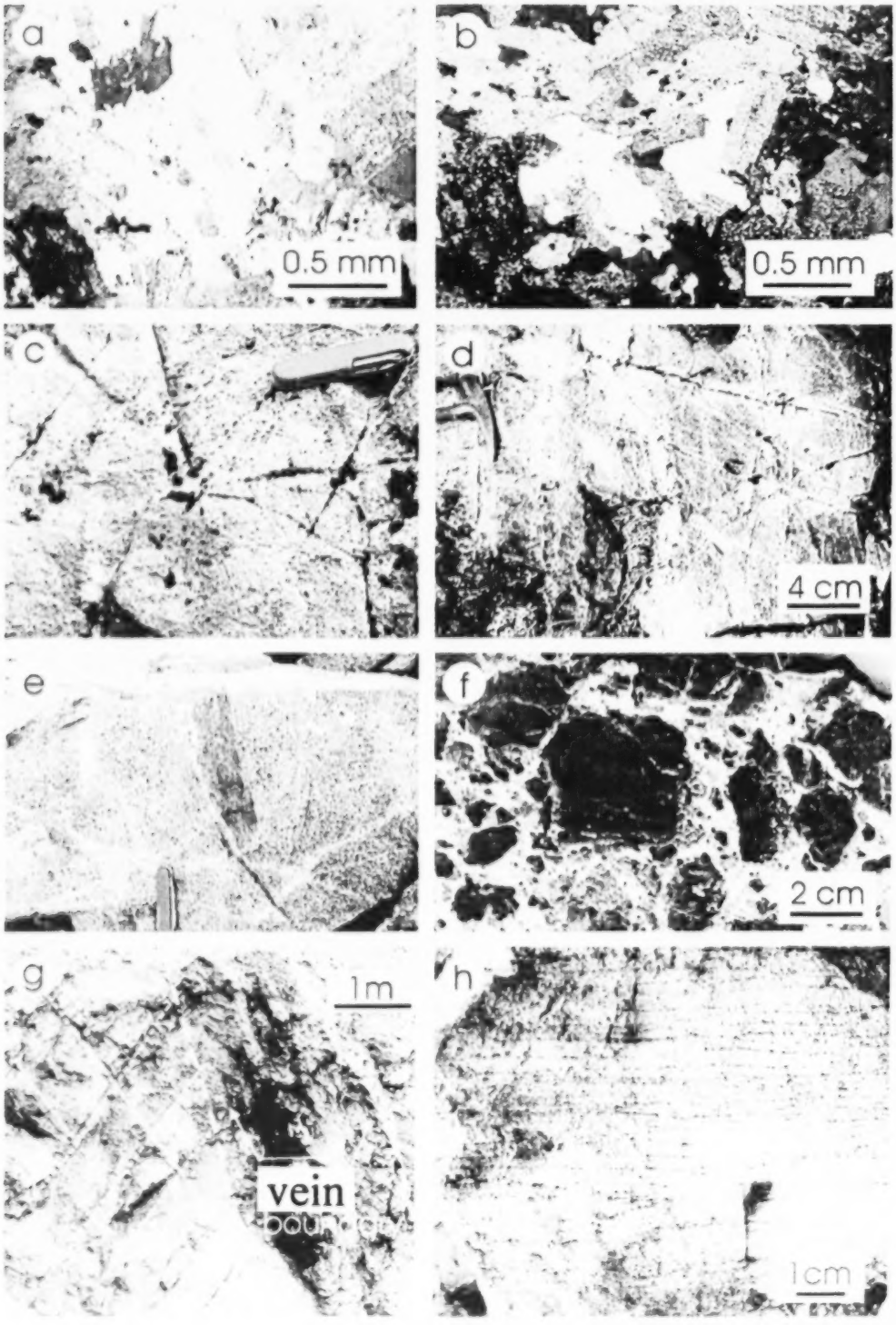
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Structural Features in the Coxheath Deposit Area

Several structural features are present in the Coxheath area that presumably represent pre-, syn- and post-mineralization phases in the area. The earliest structures are conjugate joints or fractures observed in both the diorite and volcanic rocks (Fig. 2c, d, e). The joints are moderately to steeply dipping, strike northeast and northwest (Fig. 3a), and may form a locus for both propylitic and intense carbonate alteration (Figs. 2d, e, 3b). However, no mineralization has been observed along these fractures.

Vein structures consist of two types, referred to here as stockwork and sheeted veins. Stockwork veins occur as large vein swarms and include the past-producing vein systems of the Coxheath Zone, referred to previously as the four sub-parallel shear zones known as the B, C, D and LW veins. One of these is exposed at the west end of the quarry face in the Coxheath Zone (Fig. 2g) where it can be seen to have a different orientation than the conjugate fracture sets (compare structural data in Figs. 3a and 3c). These veins consist of brittle to ductile domains of 1-2 m width that have clearly defined boundaries. Within these zones the rock is strongly deformed with abundant fractures that focused fluids, resulting in mineralized vein formation. These veins are characterized by an abundance of tourmaline and feldspar alteration. The sheeted veins (Fig. 2h) occur extensively within the Deep Pit grid area where they have northeast strikes and steep dips (Fig. 3c), are closely spaced (i.e. 100-300 m) and subparallel, and are dominated by quartz, epidote and chalcopyrite. The diorite in this area is pervasively altered with potassic, propylitic and silica types occurring.

Hydrothermal breccias occur in various places within the deposit area (Fig. 2f) where mm- to cm-size, rounded to angular fragments of volcanic rock are cemented by fine-grained silica. The breccias sometimes contain abundant (5-20%) sulphides (pyrite, chalcopyrite) intergrown with the matrix quartz.

Several late structural features occur, including ductile shear zones and brittle faults which are best observed in the Coxheath Zone area. In one location, a steep fault forms the contact between the diorite and volcanics on the east side of the quarry. The structures vary in thickness and orientation (Fig. 3d) and have variable proportions of quartz and calcite. In some veins laminated carbonate occurs with fragments of wall rock diorite; these veins may form an en-echelon array. Other veins have coarse, oriented, dogtooth carbonate filling multi-cm wide openings. Rare barite occurs in some of these veins. In thin sections, late quartz-carbonate veins are commonly seen cross-cutting earlier alteration and mineralization.

Mineralization and Alteration

Mineralization in the Coxheath area is represented in the Coxheath, Mountain and Moly (also Central) zones and the Deep Pit area (Fig. 1). As a more complete description of these areas is in preparation, only a brief summary is given here and descriptions are also found in Lynch and Ortega (1997) and Chatterjee and Oldale (1980). The Coxheath and Mountain zones contain west- to southwest-trending shear zones (Fig. 2g) containing tourmaline-sulphide veins (i.e. stockwork veins above) of variable density and width, which are bordered by an alteration assemblage that replaces the host diorite. A typical example of this is shown in Figure 4a where a vein of massive tourmaline is connected to a stockwork system of tourmaline veins which cross-cut altered diorite, now a mass of potassic and sodic feldspar. Characteristic of the potassic feldspar of this zone is the enrichment of barium (<4.5 wt. % BaO), as determined from electron microprobe analysis (DeWolfe, 2000). The tourmaline veinlets are mm to multi-cm wide and contain masses of fine-grained tourmaline or coarse acicular grains disseminated within the quartz-feldspar alteration halo (Fig. 4b). Some of the veins have a fibre texture and are coved by euhedral, acicular quartz and indicate extension prior to vein fill, whereas the finer-grained massive tourmaline reflects mostly replacement. Coring some of the areas between veins are areas of propylitic alteration containing carbonate, chlorite and epidote. Sulphides in this area include pyrite, chalcopyrite and bornite, which show a strong spatial association with tourmaline-rich areas.

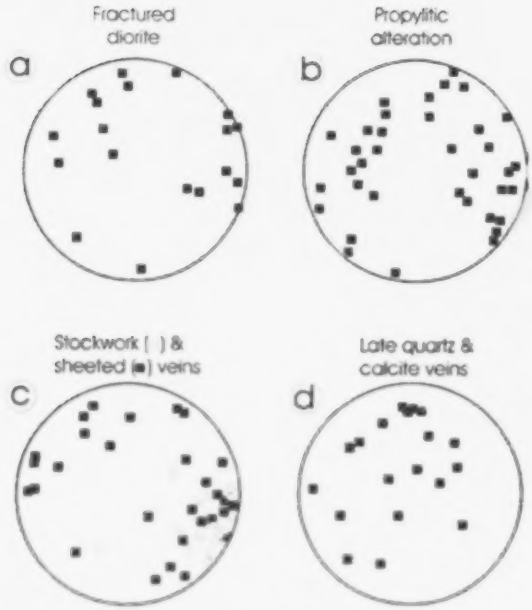


Figure 3. Stereographic plots of structural data for the Coxheath area. (a) Orientation of conjugate fractures in the diorite. (b) Orientation of propylitic alteration along fractures in the diorite and volcanic rocks. (c) Orientation of stockwork (see Fig. 4a) and sheeted veins (Fig. 4c). (d) Orientation of late quartz and carbonate veins.

A feature of the altered diorite is the presence of both Ti- and Na-rich amphibole overgrowths on early, magmatic amphibole, which occurs in close proximity to the Ba-rich feldspar (DeWolfe, 2000). The origin of these phases and how they relate to the mineralization is presently unresolved.

Mineralized breccia occurs in the Mountain Zone where altered, angular to variably corroded clasts of volcanic rock are cemented by a sulphide-bearing quartz matrix. The breccias are generally matrix supported and, therefore, must have been hydrostatically supported. This conclusion is also supported by the presence of primary, vapor-rich fluid inclusions in euhedral quartz (Fig. 4e). The clasts are intensely chloritized (to 99%) and secondary, fine-grained white mica, fine-grained anhedral quartz, rutile and leucoxene also occur. The fragments are cut by micro-veinlets of quartz that emanate from the matrix material. This quartz is characteristically undeformed, subhedral to euhedral in shape (Fig. 4d), and may contain zonally arranged, vapor-rich fluid inclusions (Fig. 4e). Sulphide minerals include pyrite and chalcopyrite. Samples of altered volcanics cut by magnetite-chalcopyrite-silica-white mica veins also occur in this area.

In the Moly Zone and Deep Pit grid chalcopyrite and molybdenite occur both in multi-cm wide quartz veins and sheeted quartz-epidote-sulphide veins (Figs. 2h, 4f). Gold in these zones is associated with high copper grades, but visible gold has not been identified. The quartz veins have silica-potassic alteration haloes which have modified the original diorite to the texture and mineralogy of a monzogranite granitic rock. One such mineralized sample containing quartz-molybdenum veins was selected for Re-Os dating (e.g. Selby *et al.*, 2002) to obtain a direct age of the molybdenum mineralization. The sheeted veins occur as a high density (100-300 m) of subparallel veinlets which are filled with variable mixtures of quartz-epidote-magnetite-hematite-chalcopyrite-bornite and also minor white mica, titantite and rutile. The titanite forms part of the alteration halo about the vein, whereas magnetite and hematite, after the magnetite, can occur within the vein and halo area. Areas between the veins may have residual plagioclase with disseminated white mica and chlorite and, in addition, this is where the anhedral to subhedral quartz occurs intergrown with the plagioclase in a graphic-like texture (Fig. 2b). The denser the concentration of the veinlets, the more complete the alteration of the host diorite, such that up to several tens of metres of altered rock contains ca. 0.5 wt.% Cu based on diamond-drill intersections.

Alteration types in the area include potassic, sodic, tourmaline and propylitic alteration. Potassic and sodic alteration are developed peripheral to areas intensely veined, such as those places where tourmaline is best developed.

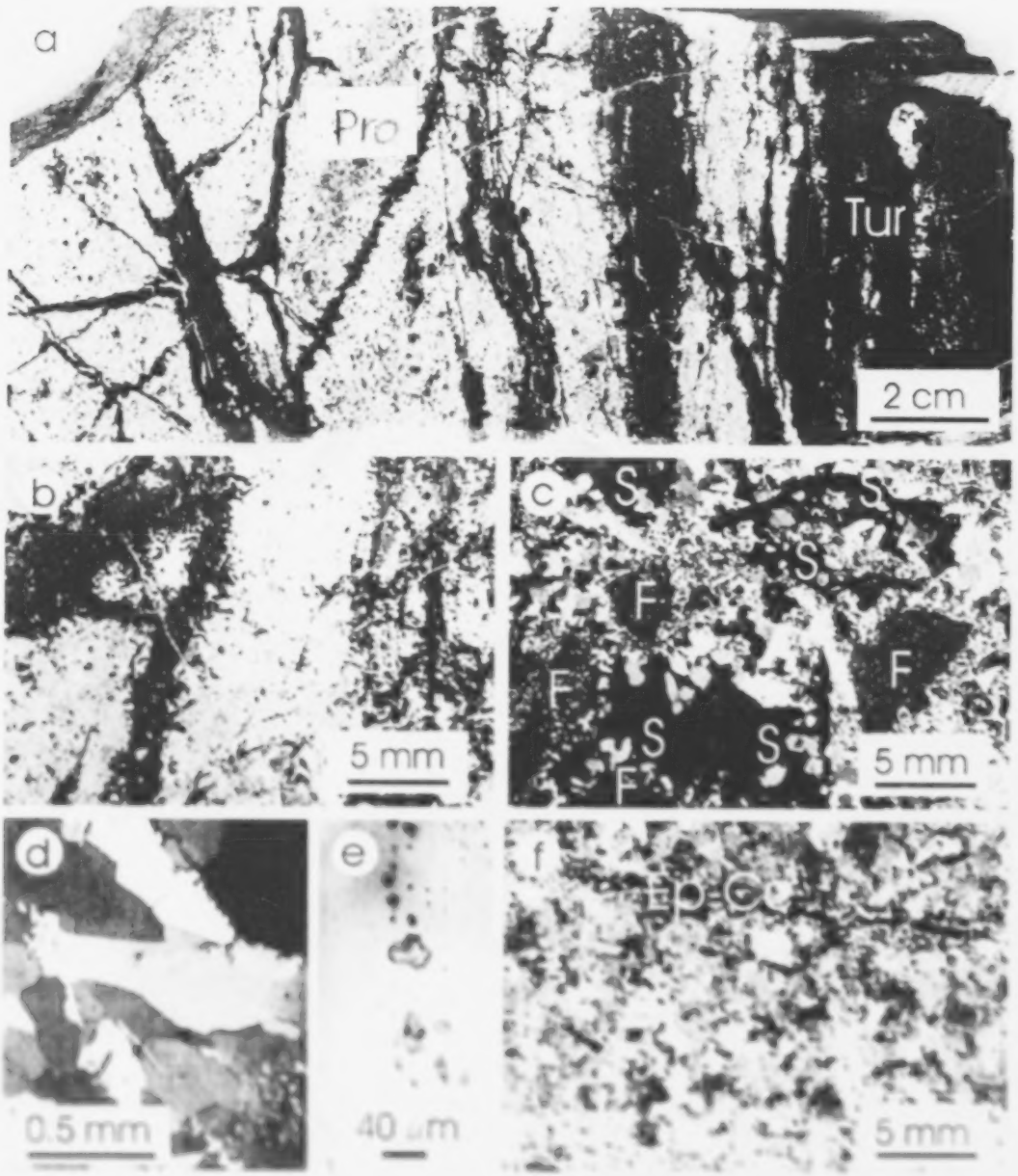
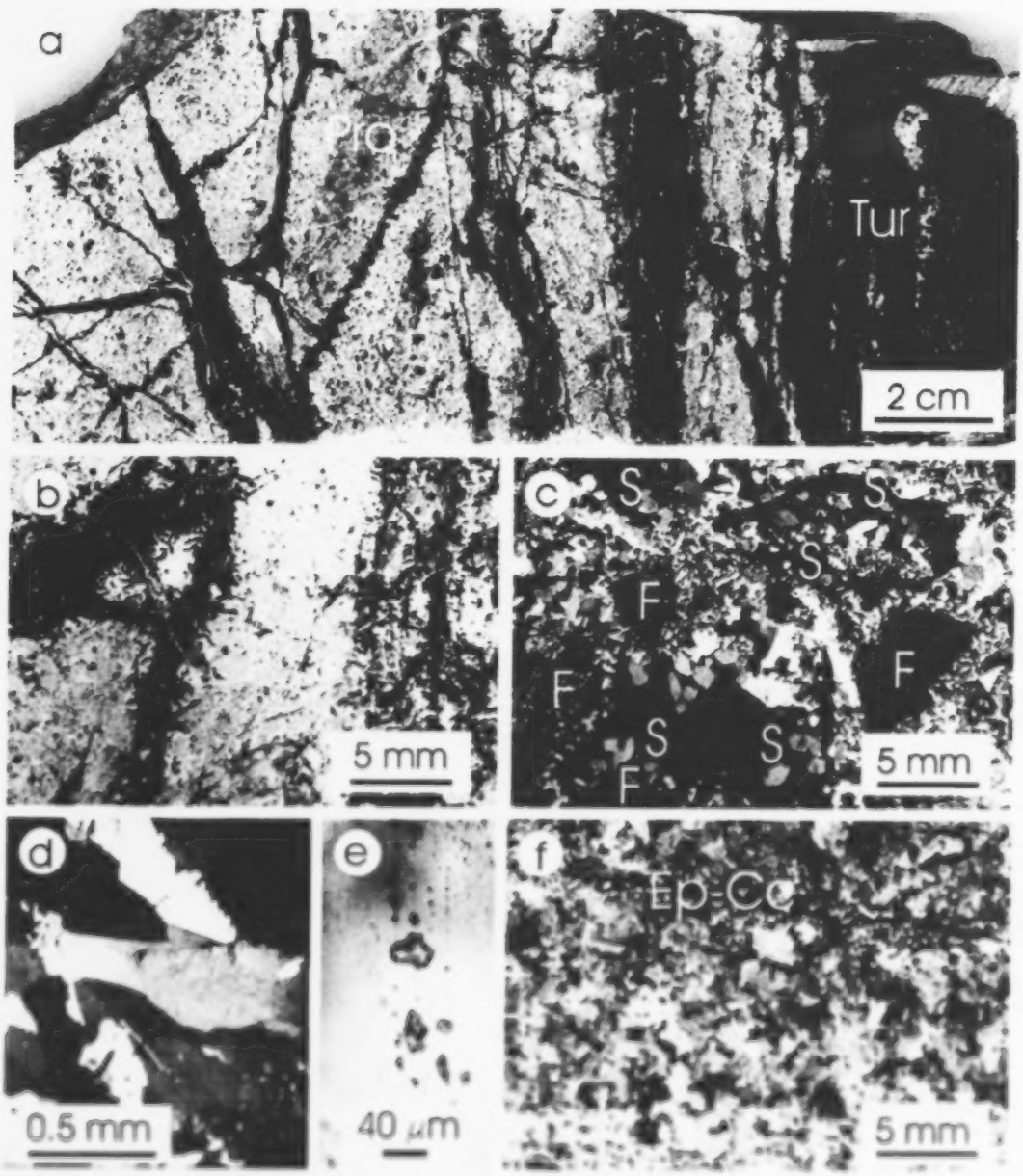


Figure 4. (a) Sample of tourmaline-rich alteration around stockwork vein system in diorite of the Coxheath Zone. Sample from west end of quarry face in Coxheath Zone (see Fig. 2g). Abbreviations for alteration types are: Kf = K-feldspar, Pro = propylitic, Tur = tourmaline. (b) Photomicrograph of sample in Figure 4a showing the tourmaline veinlets in altered diorite. Note the massive texture of the tourmaline with radiating tourmaline projecting from the massive tourmaline. Intervening material is altered diorite. (c) Silica-rich matrix to monolithic volcanic breccia from the Mountain Zone. Note the angular fragments (F) of altered andesite, pyrite and chalcopyrite (S), and euhedral quartz. (d) Photomicrograph of euhedral quartz grains in cement of breccia sample shown in Figure 4c. The quartz grains are growing around and outward from the fragments. (e) Plane of primary, vapor-rich fluid inclusions along growth zone in quartz of sample in Figure 4d. (f) Photomicrograph of sheeted vein system (see Figure 2h) showing subparallel



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Geological Features of Pyrophyllite-bearing Altered Volcanic Rocks

Approximately 4-6 km northeast of the Coxheath deposit area lies a sequence of felsic volcanic rocks, part of the Coxheath Plutonic-Volcanic Belt. These rocks contain zones of pyrophyllite developed within structural zones. Their occurrence, distribution, petrographic features and geochemistry are discussed in some detail in the following sections.

Occurrence and Distribution

Distribution of the altered volcanic rocks is shown in Figure 1 along with other known occurrences of pyrophyllite in the area. One of the areas located in Figure 1 was formerly quarried and mined by Dominion Steel Co. in the early 1900s. In the fall of 2002 trenching of this area was done by NSDNR in order to determine the extent of the pyrophyllite, assess its relationships to the surrounding rocks, and obtain samples for analysis. Trenching and location of additional outcrops in the area indicate the pyrophyllite zones: (1) are oriented in a northwest manner, (2) have both gradational and abrupt contacts with the surrounding felsic volcanics, and (3) define zones of ca. 15 m width and >150 m strike length. Their vertical dimension remains undefined, but the literature indicates that similar zones mined globally are vertically extensive and continue beyond the economic cutoff for the ore bodies. In outcrop the pyrophyllite-rich zones are not readily recognized as being significant despite the fact that they are composed predominantly of this valuable industrial mineral. However, once recognized the extent of the zone is easily determined because the outcrops are characterized by their light buff to pale pink colour and massive texture (Fig. 5a). The rock has a well developed, penetrative fabric and preferentially breaks along this direction. In addition, the pyrophyllite-rich zone in this particular area defines local topographic highs of northwest orientation.

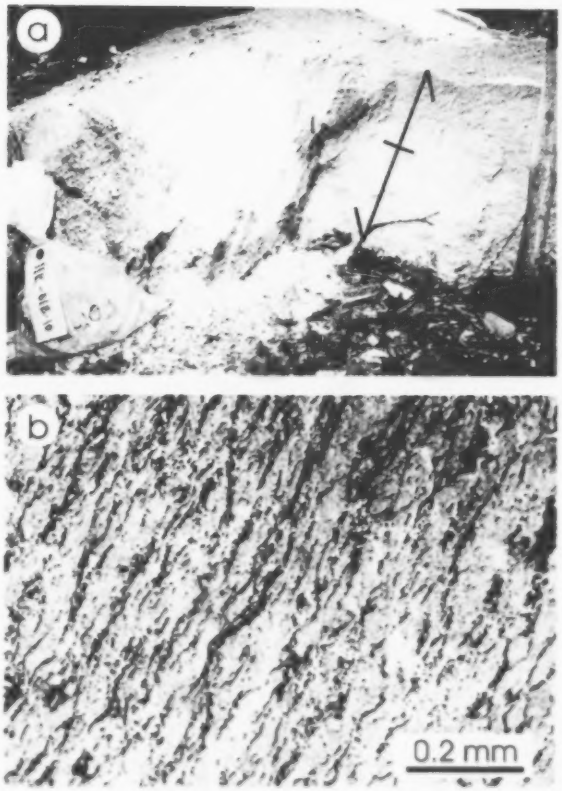

Figure 5. (a) Outcrop photo showing pyrophyllite-rich altered volcanic rock in northern part of the map area (see inset of Fig. 1). Orientation of the schistose fabric is indicated by the inclined cleavage symbol. Note hammer on right side for scale. (b) Photomicrograph of pyrophyllite-rich rock showing well-developed fabric. Dark lines defining fabric are altered oxides (i.e. rutile, leucoxene) and carbonate, whereas intervening areas are pyrophyllite and quartz.

We emphasize that previous workers had mapped out about 17 other zones of pyrophyllite in this area. Despite the general nature of the map containing these locations, the data nevertheless indicate that the zones are elongate and have variable orientations. The extent of these additional zones appears to be similar to that determined for the above mentioned zone, on the order of several hundred metres in strike length. Thus, collectively this indicates that there is significant tonnage potential for pyrophyllite.

Petrography and Mineralogy

The altered felsic volcanics are dominated by fine-grained phases that include clots of xenomorphic silica with subgrain development, abundant phyllosilicates, altered oxides (i.e. leucoxene, rutile), and carbonate. There is a well-developed planar fabric throughout (Fig. 5b) and uniform distribution of the mineral phases.

Given the very fine-grained nature and similarity of alteration minerals in volcanic rocks (i.e. various clay phases), detailed methods of mineral identification have been used to characterize the samples. In the first instance a sample of the altered volcanic rock was prepared as a polished section for examination with the electron microprobe using combined imaging and mineral analysis. Collectively, the imaging and analysis indicate the presence of quartz, pyrophyllite, diaspore and carbonate (Table 1). In addition, imaging analysis (Fig. 6) indicates the very fine-grained nature of the phases, generally several tens of microns, and their intimate intergrowth. The well-developed fabric seen in the hand sample was also seen during image analysis (e.g. Fig. 6b, c) where all the minerals were observed to be aligned parallel to this fabric, thus the minerals were either synchronous with or pre-dated fabric development.

In the second method of analysis, three samples of altered volcanics that had been crushed to <200 mesh for whole-rock chemical analysis, were analyzed using Philips Rietveld software at Queen's University, Kingston, Ontario. In this method, the X-ray lines recorded from the sample are used to determine the presence of minerals and their abundance can be quantified. The work is still in progress; however, initial results of the analysis of three samples are summarized in Table 2, where they are compared to the minerals present in high-sulphidization epithermal environments (White and Hedenquist, 1995). It is evident that there is a strong similarity between the mineralogy in the altered volcanics of Coxheath and the mineralogy expected in epithermal environments related to high-sulphidization systems.

Chemistry of the Altered Volcanic Rocks

Chemical analysis of sixteen altered volcanic rocks are presented in Table 3. Note that except for samples CB-05, 11KO1B 13 and 14, all of these samples come from the area in Figure 1 where the NSDNR trenching was done. Most of the samples are similar with respect to their degree of argillic alteration, but some differences are noted: (1) samples CB-02 and CB-05 contain some quartz veins, (2) 11K01B-13 contains a potassium-rich mineral phase, probably white mica based on the wt. % K_2O, and (3) 11K01B-14 contains albite and carbonate. The following points are noted regarding the major and minor element chemistry of these rocks (Table 3) and, for comparative purposes, they have been plotted with unaltered volcanic rocks of the Coxheath suite, grouped into basalts and andesites and rhyolites (after Barr *et al.*, 1996) in Figure 7. (1) These rocks have high silica levels typical of rhyolites, with the exception of two samples with >80 wt.% SiO_2 due to the presence of quartz veins. (2) Most samples show extreme enrichment in alumina with 18 to 25 wt. % Al_2O_3, which compares to 12-15 wt.% Al_2O_3 in the unaltered rhyolites. The exceptions to this are the two rocks that have quartz vein material that has diluted the alumina content and two samples that are not as pervasively altered. (3) The altered rocks are all extremely depleted in alkalies, with both potassium and sodium stripped in all but two samples. (4) The abundances of iron, magnesium and calcium are also very low. (5) The abundances of titanium and phosphorus are similar to unaltered felsic volcanic rocks in the area, thus these elements may be used as indicators of the primary chemistry of the altered rocks (see below).

In the Al_2O_3 versus SiO_2 plot, representative muscovite and pyrophyllite are plotted on the binary diagram along with a tie line joining quartz and pyrophyllite. The altered volcanic rocks plot along this line at mixtures of 70 to 90% by weight of pyrophyllite. Thus, the analyzed samples are clearly dominated by this mineral phase. The lack of potassium in these rocks indicates that secondary

Table 1. Representative compositions of minerals in altered volcanic rock, Cape Breton.

Sample	CB-2002	CB-2002	CB-2002	CB-2002	CB-2002	CB-2002	CB-2002
Mineral	pyrophyllite	pyrophyllite	pyrophyllite	pyrophyllite	diaspore	diaspore	diaspore
Point	1	3	4	7	2	17	22
SiO_2	65.02	67.00	67.50	67.55	0.12	0.57	1.10
Al_2O_3	30.71	28.39	28.27	27.89	83.95	82.63	81.95
FeO	-	0.12	0.20	0.09	-	0.09	0.06
MnO	0.05	0.07	0.13	-	-	0.25	0.05
CaO	0.25	0.09	-	0.13	0.07	-	0.02
Na_2O	0.12	0.07	0.01	0.11	-	0.00	0.01
Total	96.31	95.97	96.51	96.48	84.45	83.55	83.30

white mica is not present in these samples (see K_2O+Na_2O versus SiO_2 plot in Fig. 7).

In terms of the trace element data for the altered volcanic rocks (Fig. 7), the following points are highlighted and again they are compared to data for unaltered volcanic rocks from Barr *et al.* (1996). (1) In plots of silica and titanium versus zirconium, the altered samples appear to overlap in part the field for unaltered volcanics. This is also seen in the Ti/Zr versus Zr plot, although there appears to be a slight enrichment of some samples in Zr. The nature of this Zr enrichment will be examined in more detail below in relation to mass gains and losses associated with the alteration. (2) In terms of Zr-Y, the altered samples clearly define a separate field, except for the two samples with only partial loss of the alkalies, in which case the Zr/Y values are similar to those in fresh volcanics. This is also seen in the plot of Ti/Zr versus Y, which highlights the Y-depleted nature of the samples. Similarly, in the Zr-Nb plot the altered samples define a distinct field and the two least altered samples fall in the same area as the unaltered volcanics. This suggests that there may be depletion of Nb similar to the behaviour of Y.

Given that Ti and Zr in the altered rocks appear to be similar to the levels in the fresh felsic volcanic rocks, the Ti/Zr ratio has been used as a proxy for the primary, unaltered signature of the pyrophyllite-bearing rocks and a measure of the degree of fractionation since Zr is an incompatible element in this suite. Thus, using the Ti/Zr ratio it is evident that there is a slight enrichment of Ga in the altered rocks, but extreme enrichment in Pb (to 294 ppm), Ba (to 3.3 wt. %), and Sr (to 2387 ppm). Although not identified yet, the analyses clearly indicate that barite should be present in these rocks. In binary plots of Ba, Sr and Pb it is evident that these elements show a strong positive correlation. These elemental enrichments are significant as they are common in high-sulphidization systems (e.g., White and Hedenquist, 1995) and provide evidence of a magmatic fluid component to these rocks.

An important aspect of the geochemistry of altered rocks is whether the elemental enrichment/depletion is a result of volume or mass changes (Leitch and Lentz, 1994). For example, changes in the density of a sample due to uptake of volatiles (e.g. H_2O) can change the concentration of elements (i.e. decrease apparent abundance) without gain or loss of these elements. Using the graphical method of Grant (1987), the average fresh and altered felsic volcanic rocks are plotted in a binary plot and two scenarios are examined, one being conservation of Al and the other conservation of Si (Fig. 8). Before further discussion it is important to emphasize that the primary nature of the altered rocks was probably rhyolite given that their Ti/Zr ratios are identical to those for the unaltered rhyolites of Barr *et al.* (1996) and quite distinct from Ti/Zr ratios of the less evolved volcanics. The primary nature of the rocks having been established, it is noted that conservation of Al

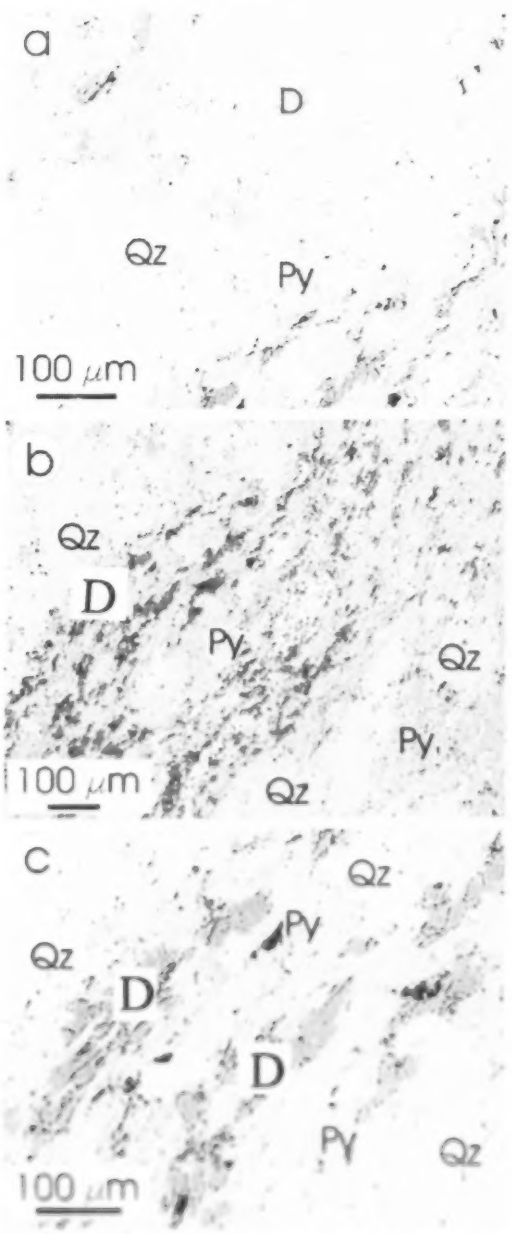

Figure 6. Back scattered electron images of sample in Figure 5b illustrating the mineralogy of the altered volcanic rock. In the images the mineral with the lower average atomic number is dark and the one with the highest average atomic number is brightest. Abbreviations are as follows: pyrophyllite (Py), diaspore (D) and quartz (Qz). The bright material defining a NE-fabric in 6b is rutile (i.e. Ti- rich), hence its brightness in the imaging.

indicates that Zr and Ga contents have also been conserved, but that there has been considerable loss of Si (i.e., 25%). Such loss of silica is considered unlikely given the already high levels for this element and that an upper limit of ca. 73 wt. % might be assumed given the nature of the precursor (rhyolite). In the alternative scenario, Si is assumed to have been conserved. In this case there is small enrichment of Al, Ga and Zr, which is what was suggested from the binary plots in Figure 7 (i.e. Zr and Ga versus Ti/Zr). This second scenario is considered more realistic for the following reasons. (1) The slight enrichment of Zr observed in these rocks is explained, whereas in scenario 1 a special suite of Zr-rich felsic volcanics is inferred, which is contradicted by the fact that the two least altered rocks have Zr values similar to the unaltered rocks. (2) The slight enrichment in Ga is accounted for in the altered rocks. (3) The depletion of Y of about 55% gives recalculated primary values of ca. 35-40 ppm that are consistent with Y in the unaltered rocks for similar Zr contents. (4) There is an increase in the aluminum contents of the rocks, as suggested by the absolute values of 18-25 wt. % Al_2O_3.

Discussion and Conclusions

The foregoing sections have presented the salient aspects of the geological setting, petrology, mineralogy and alteration, and nature of mineralization in two disparate systems, one a porphyry-type environment and the other an epithermal, high-sulphidization system. We suggest here that the relationship between the diorite-hosted, porphyry-style Cu-Mo-Au mineralization and the occurrence of extensive zones of argillically altered rocks (i.e. volcanics containing pyrophyllite, alunite, topaz, diaspore, and kaolinite) in the overlying coeval volcanics is more than coincidental. For example, we highlight the presence of celsian (i.e. Ba-rich) feldspar in the altered diorite, barite in late veins of the Coxheath area, and the anomalous content of up to 3% barium in the pyrophyllite rocks. Thus, we suggest the linking of these two disparate systems into a single deposit model based on the present knowledge of porphyry-epithermal systems. It has been suggested for some time that there is a continuum from the underlying coeval intrusive

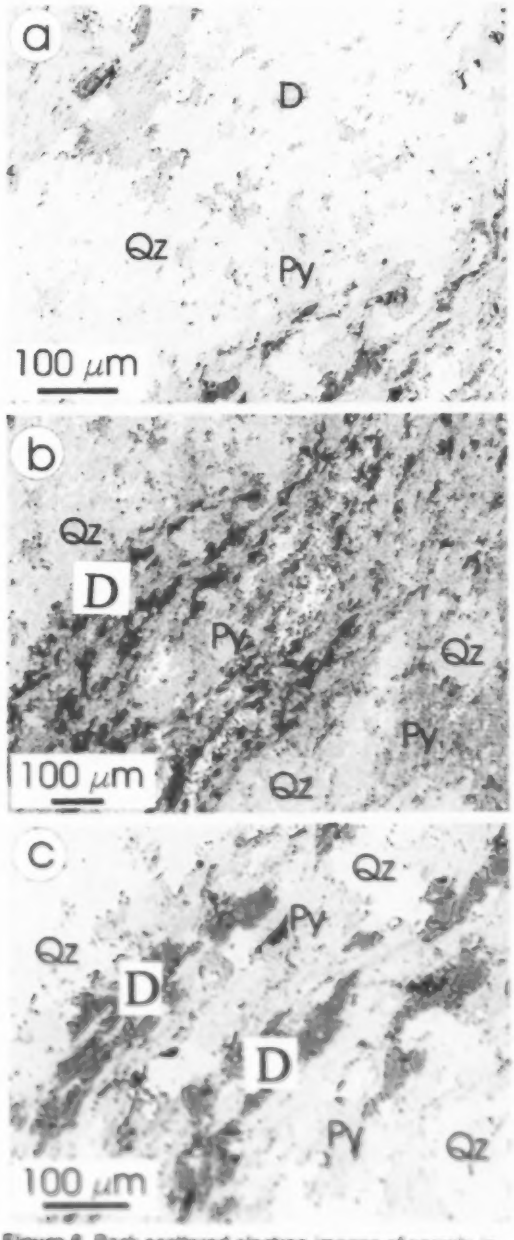

Figure 6. Back scattered electron images of sample in Figure 5b illustrating the mineralogy of the altered volcanic rock. In the images the mineral with the lower average atomic number is dark and the one with the highest average atomic number is brightest. Abbreviations are as follows: pyrophyllite (Py), diaspore (D) and quartz (Qz). The bright material defining a NE-fabric in 6b is rutile (i.e. Ti- rich), hence its brightness in the imaging.

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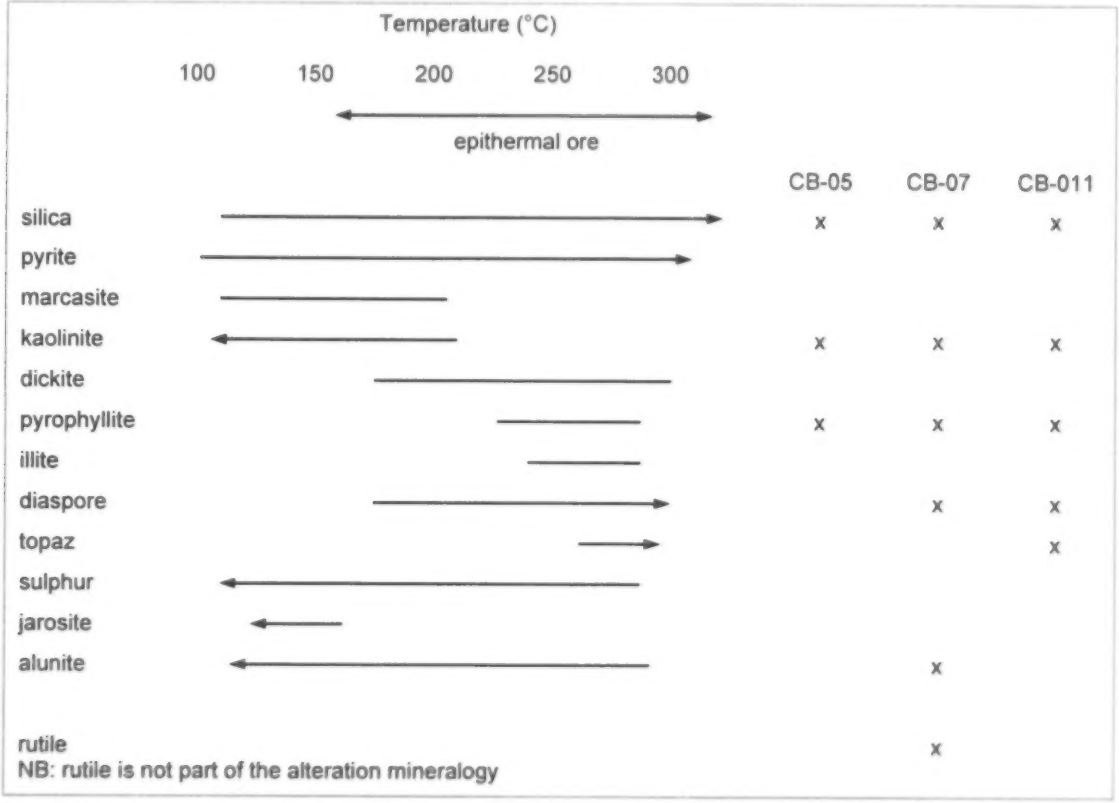
Table 2. Summary of the mineralogy of samples from altered volcanic rocks, compared to the mineralogy of high-sulphidization systems (after White and Hedenquist, 1995).



rocks to the petrogenetically related volcanic carapace (e.g. Sillitoe, 1973). More detailed studies of mineralized districts over the past few decades have made more clear the relationship between the magmatic-source fluids and extensively altered and mineralized zones in high-level epithermal environments (e.g. Hayba *et al.*, 1985; White and Hedenquist, 1995). The alteration zones in these environments are distinguished based on their mineralogy such that low- and high-sulphidization systems are recognized and are considered to reflect the contribution of magmatic sulphur, originating as SO_4, from a shallow magmatic system. The mineral assemblage identified in the pyrophyllite-rich zones is indicative of a high-sulphidization system and suggests, therefore, an underlying magmatic source for sulphur. This conclusion suggests that there may also be potential for base- and precious-metal mineralization, and the relative proximity of the Coxheath mineralized environment further supports this model.

An example of a mineralized district that might be used as a comparative model for the Coxheath area is found in the Maricunga belt of northern Chile. In this region, Vidal and Sillitoe (1991) integrate data from several porphyry-epithermal deposits into a single unified deposit model. The richly mineralized area of this part of the Andes is underlain by an igneous and sedimentary basement of Paleozoic and Mesozoic age, which is overlain by a richly mineralized Miocene andesitic-(dacitic) stratovolcano landscape which is cut, at depth, by composite porphyry stocks of diorite and quartz diorite composition. In the porphyry deposits, gold-copper mineralization is associated with K-silicate alteration, whereas in the higher-level volcanic rocks gold is found in zones containing pyrite- and alunite-rich advanced argillic alteration, with barite, native sulphur, enargite and vein-type mineralization. Minor inter- to late-mineralization hydrothermal breccias are commonly present. Examination of one of the deposits of this belt in

Table 3. Whole-rock geochemistry of altered volcanic rocks in the Late Proterozoic Coxheath Group, Cape Breton Island.

Sample	CB-01	CB-02	CB-05	CB-06	CB-07	CB-08	CB-09	CB-10	CB-11	11K01B 13	11K01B 14	11K01B 15	11K01B 16	11K01B 17	11K01B 18	11K01B 19
Major elements (wt. %):																
SiO2	73.26	83.77	84.09	71.71	71.16	70.7	69.94	71.82	67.02	72.73	69.87	69.67	75.24	66.55	71.13	71.18
TiO2	0.336	0.256	0.405	0.688	0.664	0.764	0.69	0.659	0.649	0.428	0.266	0.637	0.563	0.569	0.524	0.63
Al2O3	20.26	11.78	11.82	20.39	21.73	21.81	22.5	21.07	25.11	14.34	10.68	24.1	18.61	19.48	22.02	21.85
Fe2O3	0.2	0.26	0.26	0.14	0.35	0.53	0.31	0.21	0.15	1.68	1.6	0.11	0.18	0.18	0.17	0.18
MnO	0.001	0.003	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.007	0.103	0.073	<0.001	<0.001	0.001	<0.001	<0.001
MgO	0.02	<0.01	<0.01	0.01	0.01	0.01	0.02	0.01	0.02	2.06	0.21	0.02	0.02	0.02	0.01	0.01
CaO	0.12	0.11	0.05	0.55	0.08	0.06	0.07	0.06	0.15	0.44	5.4	0.09	0.11	0.05	0.06	0.07
Na2O	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	4.06	<0.01	<0.01	0.03	<0.01	<0.01
K2O	0.01	0.02	0.06	0.03	0.06	0.03	0.04	0.01	0.01	3.93	1.8	0.03	0.07	0.04	0.02	0.02
P2O5	0.162	0.072	0.061	0.19	0.295	0.213	0.232	0.126	0.177	0.058	0.059	0.217	0.255	0.187	0.156	0.162
LOI	4.13	2.4	2.13	4.65	4.84	5.54	4.72	4.33	5.42	3.69	4.11	4.78	4.06	5.1	5.23	4.84
Totals	98.9	98.67	98.88	98.36	99.19	99.66	98.52	98.3	98.71	99.48	98.13	99.65	99.11	92.21	99.32	98.94
Trace elements (ppm):																
V	80	36	57	79	72	81	75	72	74	54	31	79	65	93	68	68
Cr	12	14	22	9	9	10	12	14	7	8	21	9	4	4	6	6
Co	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Zr	386	192	214	300	419	394	375	265	320	237	164	335	340	422	310	325
Ba	1448	1241	299	1521	519	70	545	<25	<25	314	433	166	278	33077	7304	1497
La	46	21	37	63	44	51	36	64	69	25	30	36	57	52	50	65
Nd	36	22	28	41	30	38	22	36	45	13	32	34	45	96	48	57
Ni	4	5	6	6	6	6	6	4	7	6	<3	4	6	<3	6	6
Cu	11	13	11	10	20	18	16	10	10	<5	6	12	12	12	13	10
Zn	20	20	22	20	19	19	19	19	18	250	35	17	19	21	19	18
Ga	19	17	14	19	19	18	19	18	21	17	7	21	23	20	22	20
Rb	<2	3	4	2	>2	<2	<2	2	<2	159	56	<2	<2	<2	<2	<2
Sr	763	619	368	859	2387	1634	1737	430	742	39	172	1139	1325	2238	1017	737
Y	19	14	15	19	22	17	16	17	13	41	35	10	16	11	11	15
Nb	8	6	6	8	8	8	8	7	8	10	9	6	7	9	8	8
Pb	49	38	25	48	87	75	84	39	57	41	19	68	72	294	168	99
Th	9	<2	19	17	5	8	8	17	24	8	4	10	12	10	21	19
U	<1	2	4	<1	<1	<1	<1	2	<1	5	5	<1	<1	<1	<1	<1

Analysis done at the regional XRF facility, St. Mary's University, Halifax

more detail is provided by Vila *et al.* (1991), who describe the nature of the Marte deposit of northern Chile which produced produced 66 tonnes of gold out of a porphyry gold system. The mineral deposit lies within a hornblende-biotite diorite stock that is part of a coeval andesitic stratovolcano. Gold distribution is related to a quartz vein stockwork surrounded by intermediate argillic alteration (chlorite-sericite-clay) with disseminated pyrite-Fe oxides. Minor chalcopyrite, molybdenite, tennantite, bornite and enargite occur, and remnant hydrothermal biotite and K-feldspar attest to earlier K-silicate alteration. Traces of tourmaline are noted. Intrusion breccia occurs, which is locally transected by hydrothermal breccias. An erosional remnant of the andesitic volcanic roof to the stock is largely replaced by a chalcedony- and alunite-rich advanced argillic assemblage, which is part of a larger tabular alteration zone.

As noted by Lynch and Ortega (1997), the features of the Coxheath Cu-Au-Mo system bear many similarities to the porphyry gold deposit type discussed by Sillitoe (1993). In addition, we have shown that the occurrence of altered volcanic rocks in the petrogenetically related volcanic carapace can be interpreted in the context of a high-sulphidization system. The present distribution of plutonic and volcanic rocks in this area suggest that this system has been tilted to expose the remnants of a porphyry-epithermal system of Precambrian age. Although additional work is clearly required to refine this model, it is felt that the geological features of the two systems have been documented sufficiently to support the model presented, and is testament to the occurrence and preservation of high-level hydrothermal systems back into the Late Proterozoic. Further evidence for this model and the potential for precious-metal mineralization is the occurrence of other high-sulphidization systems of Late Proterozoic age in the Avalon Zone of the Appalachians (e.g. Dubé *et al.*, 1998; O'Brien *et al.*, 1998).

References

Barr, S. M., White, C. E. and Macdonald, A. S. 1996: Stratigraphy, tectonic setting, and geological history of Late Precambrian volcanic-sedimentary-plutonic belts in southeastern Cape Breton Island, Nova Scotia; Geological Survey of Canada Bulletin 486, 84 p.

Chatterjee, A. K. and Oldale, H. R. 1980: Porphyry copper-molybdenum ± gld mineralization at Coxheath; Geological Association of Canada-Mineralogical Association of Canada, Field Trip Guidebook, v. 6, p. 3-10.

DeWolfe, J. C. 2000: Geological investigation of the Coxheath Cu-Mo-Au deposit, Cape Breton Island, Nova Scotia: Structurally controlled porphyry-type mineralization; Unpublished B.Sc. thesis, St. Mary's University, Halifax, 128 p.

Dilles, J. H. and Einaudi, M. T. 1992: Wall-rock alteration and hydrothermal flow paths about the Ann-Mason porphyry copper deposit, Nevada: A 6 km vertical reconstruction; Economic Geology, v. 87, p. 1963-2001.

Dubé, B., Dunning, G., and Lauzière, K. 1998: Geology of the Hope Brook Mine, Newfoundland, Canada: a preserved Late Proterozoic high-sulphidization epithermal gold deposit and its implications for exploration; Economic Geology, v. 93, p. 405-436.

Grant, J. A. 1986: The isocon diagram - a simple solution to Gresen's equation for metasomatic alteration; Economic Geology, v. 81, p. 1976-1982.

Gustafson, L. B. and Titley, S. R 1978: Preface; *in* Porphyry deposits of the southwestern Pacific Islands and Australia; Economic Geology, v. 73, p. 597-599.

Hayba, D. O., Bethke, P. M., Heald, P. and Foley, N. K. 1985: Geologic, mineralogic, and geochemical characteristics of volcanic-hosted epithermal precious-metal deposits; *in* Geology and Geochemistry of Epithermal Systems, eds. B. R. Berger and P. M. Bethke; Reviews in Economic Geology, v. 2, p. 129-167.

Hedenquist, J. W., Arribas, A., Jr., and Reynolds, T. J. 1998: Evolution of an intrusion-centered hydrothermal system: Far Southeast-Lepanto porphyry and epithermal Cu-Au deposits, Philippines; Economic Geology, v. 93, p. 373-404.

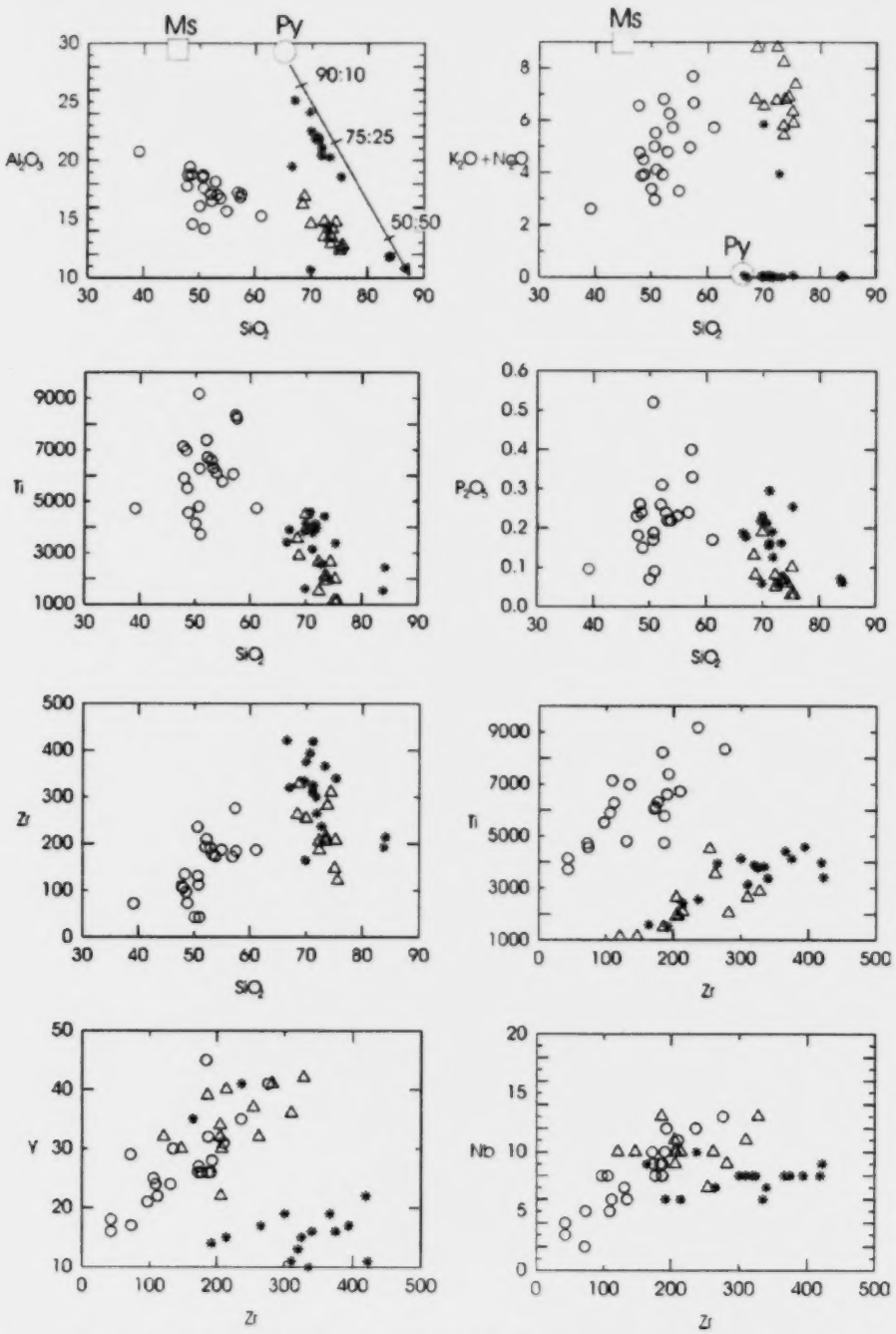


Figure 7. Binary element plots for suite of samples from the pyrophyllite-rich volcanic rocks (*) compared to the data base of Barr *et al.* (1996) for andesite (o) and rhyolite (▲).The abbreviations in the top plots are for muscovite (Ms) and pyrophyllite (Py). The tie line with numbers relates to the proportions of pyrophyllite and quartz mixtures, and indicate that the whole-rock samples in this study have mixtures of about 90:10 to 50:50 of these mineral phases. The arrow on the tie line points to 100% SiO_2 or quartz. Note that in the Pb versus Ti/Ar plot one sample is enriched in Pb (to 294 ppm).

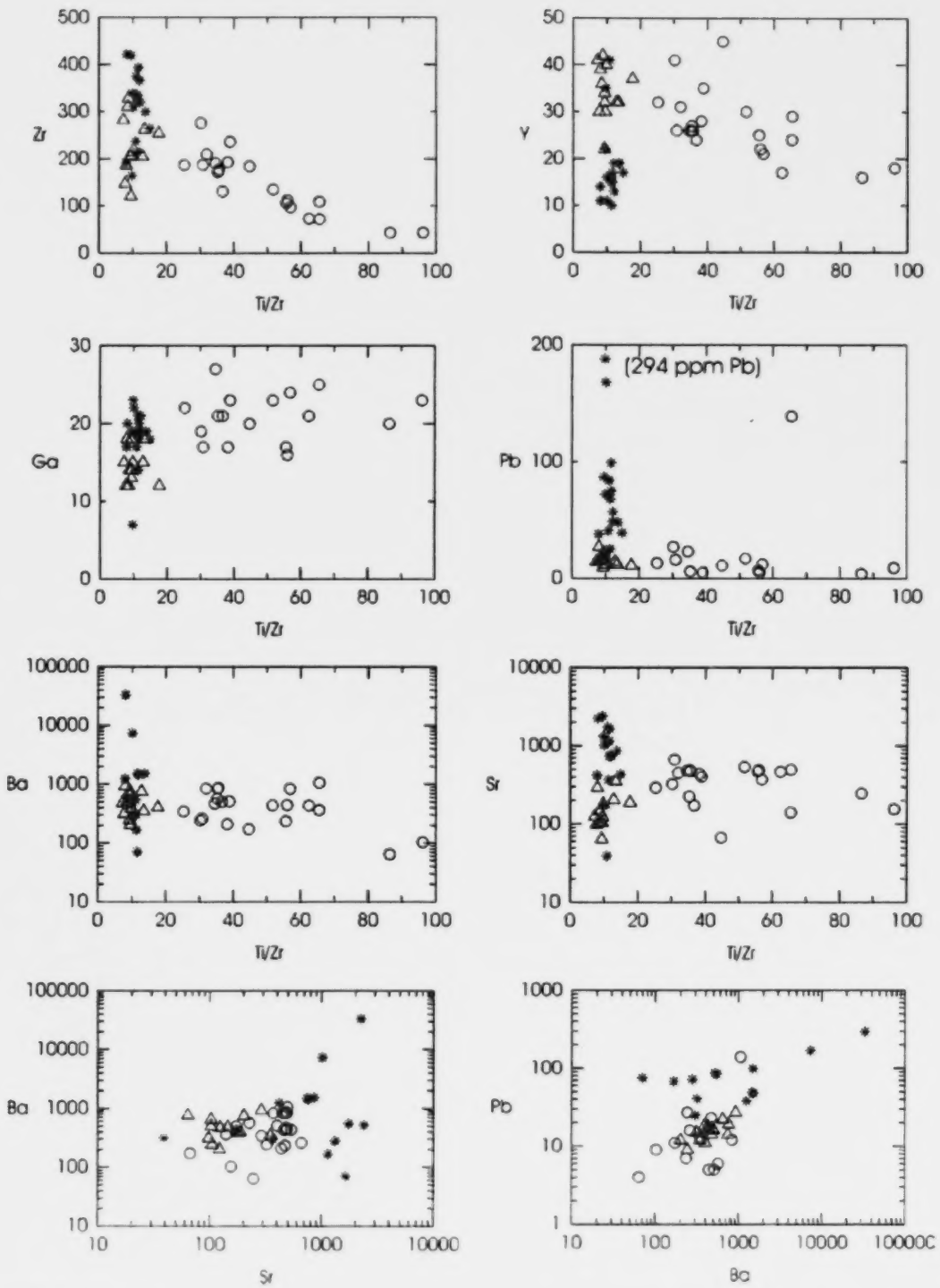


Figure 7. continued

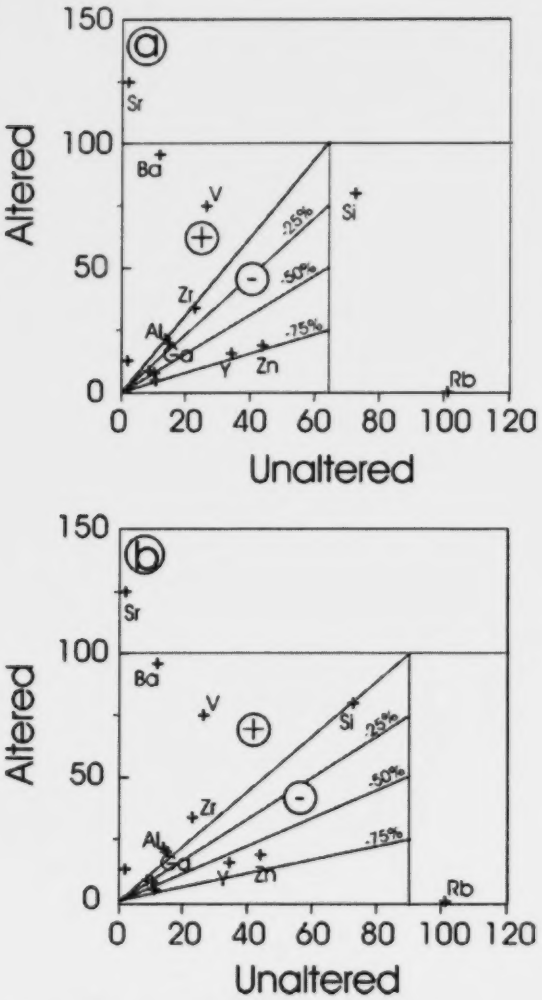


Figure 8. Isocon plots (Grant, 1986) showing the relationship between the average rhyolite of Barr et al. (1996) and the average altered volcanic or pyrophyllite-rich rock of this study. The inclined line is an inferred constant mass line and the (+) and (-) signs refer to elemental gains and losses, respectively, for elements in the altered rock compared to the fresh rock. Two scenarios are represented here: (a) Al is inferred to have been conserved, (b) silica is inferred to have been conserved. The latter is the preferred interpretation, as discussed in the text.

Hollister, V. F., Potter, R. R. and Barker, A. L. 1974: Porphyry-type deposits of the Appalachian Orogen; Economic Geology, v. 69, p. 618-630.

Keppie, J. D. and Dostal, J. 1991: Late Proterozoic tectonic model for the Avalon terrane in Maritime Canada; Tectonics, v. 104, p. 842-850.

Kirkham, R. V. and Soregaroli, A. E. 1975: Preliminary assessment of porphyry deposits in the Canadian Appalachians; Geological Survey of Canada, Paper 75-1, Pa A, p. 249-252.

Kontak, D. J., DeWolfe, J. C. and Longstaffe, F.2001: Geological investigations of the Coxheath Cu-Mo-Au system, Cape Breton Island, Nova Scotia: structurally controlled porphyry-type mineralization; Geological Association of Canada-Mineralogical Association of Canada, Abstract Volume, v. 26, p. A78.

Leitch, C. H. B. and Lentz, D. R. 1994: The Gresens approach to mass balance constraints of alteration systems: Methods, pitfalls, examples; *in* Alteration and alteration processes associated with ore-forming systems, ed. D. R. Lentz; Geological Association of Canada, Short Course Notes, v. 11, p. 161-192.

Lowell, J. D. and Gilbert, J. M. 1970: Lateral and vertical alteration - mineralization zoning in porphyry ore deposits; Economic Geology, v. 65, p. 373-408.

Lynch, G. and Ortega, J. 1997: Hydrothermal alteration and tourmaline-albite equilibria at the Coxheath porphyry Cu-Mo-Au deposit, Nova Scotia; Canadian Mineralogist, v. 35, p. 79-94.

Mitchell, A. H. G. and Garson, M. S. 1981: Mineral Deposits and Global Tectonic Settings; Academic Press Geology Series, Academic Press Inc., London, 405 p.

O'Brien, S. J., Dubé, B. and O'Driscoll, C. F. 1999: High-sulphidization, epithermal-style hydrothermal systems in Late Neoproterozoic Avalonian rocks on the Burin Peninsula, Newfoundland: Implications for gold exploration; *in* Current Research, Newfoundland Department of Mines and Energy, Report 99-1, p. 275-296.

Oldale, H. R. 1967: A century of mining exploration and development -Coxheath Hills, Cape Breton; Canadian Institute of Mining and Metallurgy Bulletin, v. 60, p. 1411-1419.

Ortega, J. and Lynch, G. L. 1994a: Geological map of the Coxheath area, Cape Breton, Nova Scotia; Nova Scotia Department of Mines and Energy Open File Map 94-007.

Ortega, J. and Lynch, G. L. 1994b: Mineralogical map of the Coxheath area, Cape Breton, Nova Scotia; Nova Scotia Department of Mines and Energy Open File Map 94-008.

Selby, D., Creaser, R. A., Hart, C. R., Rombach, C. .S., Thompson, J. F. H., Smith, M. T., Bakke, A .A. and Goldfarb, R. J. 2002: Absolute timing of sulfide and gold mineralization: A comparison of Re-Os molybdenite and Ar-Ar methods fro the Tintina gold belt, Alaska; Geology, v. 30, p. 791-194.

Sillitoe, R. H. 1973: Tops and bottoms of porphyry copper deposits; Economic Geology, v. 68, p. 799-815.

Sillitoe, R. H. 1976: Andean Mineralization: a model for metallogeny of convergent plate margins; *in* Metallogeny and Plate Tectonics, ed. D. F. Strong; Geological Association of Canada, Special Paper 14, p. 59-100.

Sillitoe, R. H. 1993: Gold-rich porphyry copper deposits: geological model and exploration implications; *in* Mineral Deposit Modeling, eds. R. V. Kirkham, W. D. Sinclair, R. I. Thorpe and J. M. Duke; Geological Association of Canada, Special Paper 40, p. 465-478.

Titley, S. R. and Beane, R. E. 1981: Porphyry copper deposits; Economic Geology 75th Anniversary Volume, p. 214-269.

Vidal, T. and Sillitoe, R. . 1991: Gold-rich porphyry systems in the Maricunga Belt, northern Chile; Economic Geology, v.86, p. 1238-1260.

Vidal, T., Sillitoe, R. H., Betzhold, J. and Viteri, E. 1991: The porphyry gold deposit at Marte, northern Chile; Economic Geology, v. 86, p. 1271-1286.

White, N. C. and Hedenquist, J. W. 1995: Epithermal gold deposits: styles, characteristics and exploration; Society of Economic Geologists Newsletter, no. 23, p. 1, 9-13.

Geoscience Editing and Publishing

D. R. MacDonald, B. L. MacDonald and J. S. Saunders

Publications play an important role in delivering geoscience information for the Mineral Resources Branch, educating the public, and conveying the professional image established by the branch. A publication is often the first chance we have to make an impression on someone who comes into contact with the Department of Natural Resources.

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The role of the geoscience editing and publishing group in the Geoscience Information Services Section can be roughly divided into two parts. The first part involves editing a manuscript (report, article or map) to the author's satisfaction, while at the same time applying the branch standards for style and content in the interest of our readers. Editor Doug MacDonald carries out this work for the Minerals and Energy Branch. The second part involves producing a published document. The editor works with desktop publishing technicians Barb MacDonald and Susan Saunders to produce publications.

Editing

In the Minerals and Energy Branch, all scientific publications must be reviewed by at least one geoscientist who has not contributed to the research being presented. This process is called peer review and finding a suitable reviewer is usually the editor's first task after receiving a manuscript. The editor assigns the manuscript to a reviewer who is experienced in the field of study being presented by the author. The editor supplies the reviewer with detailed guidelines to direct the review toward the most critical scientific aspects of the manuscript. The reviewer's comments are then given to the author so that the manuscript can be revised in an effort to improve its scientific content. Open File Reports and Open File Maps are used to release information as soon as possible, and may be approved for publication after peer review, revision by the author and minimal editing.

Resubmission of the manuscript by the author after peer review initiates the next step in the editorial process, often called substantive editing. This step may require re-writing parts of the document, re-organizing sections, and generally suggesting ways that authors can improve the presentation of their research for the intended readers.

Another aspect of the editorial process is often referred to as copy editing. This function requires careful attention to every detail in a document in order to meet the branch publication standards. For the Mineral Resources Branch, these standards reflect those used by the Geological Survey of Canada. Some standards, such as consistent capitalization, spelling and punctuation, are easily applied. Others may require much more time and effort, such as accurate citation and listing of references, and making sure that tables, maps and drawings meet the appropriate specifications.

Publishing

The final appearance of a publication is largely determined by the publication team, which includes an editor and a desktop publishing technician. This function consists of preparing camera-ready (or Internet-ready) manuscripts for publication, and involves words, figures, tables and other design

MacDonald, D. R., MacDonald, B. L. and Saunders, J. S. 2003: *in* Mineral Resources Branch, Report of Activities 2002; Nova Scotia Department of Natural Resources, Report 2003-1, p. 89-90.

elements that are electronically composed using a variety of publishing applications, such as Microsoft Word® and Publisher®, Corel WordPerfect®, and Adobe Acrobat®. Manuscripts travel back and forth between the editor and the desktop publishing technician many times before they are ready to be published, either on paper or on-line.

The following publications were released in 2002:

Contribution Series

CS ME 2002-1 Fires Sweep Across the Mid-Cretaceous Landscape of Nova Scotia, by A. C. Scott, R. R Stea, 2002; *in* Geoscientist, v. 12, p. 4-6.

CS ME 2002-2 Ar^{40}/Ar^{39} Dating of Hydrothermal Biotite from High-grade Gold Ore, Tangier Gold Deposit, Nova Scotia: Further Evidence for 370 Ma Gold Metallogeny in the Meguma Terrane, by D. J. Kontak, D. A. Archibald, 2002; *in* Economic Geology, v. 97, p. 619-628.

CS ME 2002-3 Ice Etchings, by R. R. Stea, G. A. O'Reilly, 2002; *in* Canadian Chemical News, v. 54, p. 29-30.

CS ME 2002-4 A Petrological, Geochemical, Isotopic and Fluid-inclusion Study of 370 Ma Pegmatite-aplite Sheets, Peggys Cove, Nova Scotia, Canada, by D. J. Kontak, J. Dostal, T. K. Kyser, D. A. Archibald, 2002; *in* Canadian Mineralogist, v. 40, p. 1249-1286.

CS ME 2002-5 Late-stage Crystallization History of the Jurassic North Mountain Basalt, Nova Scotia, Canada. 1. Textural and Chemical Evidence for Pervasive Development of Silicate-liquid Immiscibility, by D. J. Kontak, M. Y. De Wolfe De Young, J. Dostal, 2002; *in* Canadian Mineralogist, v. 40, p. 1287-1311.

CS ME 2002-6 Petrology, Age, and Tectonic Setting of the White Rock Formation, Meguma Terrane, Nova Scotia: evidence for Silurian Continental Rifting, by L. A. MacDonald, S. M. Barr, C. E. White, J. W. F. Ketchum, 2002; *in* Canadian Journal of Earth Sciences, v. 39, p. 259-277.

Newsletter

Nova Scotia Minerals Update, volume 19, numbers 1, 2, 3 and 4.

Open File Map

OFM ME 2002-1 Geological Map of Central Musquodoboit (part of NTS Sheet 11E/03) Colchester and Hants Counties, by R. J. Horne and M. S. King, 2002, scale 1:20 000.

Open File Report

OFR ME 2002-1 Compilation of salt analysis from Domtar Inc. diamond-drill core, Kingsville, Inverness County, Cape Breton Island, by R. C. Boehner.

Reports

Report ME 2002-1 Minerals and Energy Branch Report of Activities 2001, ed. D. R. MacDonald, 221 p.

Report ME 2002-2 Mining Matters for Nova Scotia 2002: Opportunities for Economic Development, ed. D. R. MacDonald, 30 p.

Mineral Exploration Activity in Nova Scotia, 2002

P. D. McCulloch

Mineral Exploration Monitoring

Monitoring of mineral exploration activity in Nova Scotia is co-ordinated through the Registry of Mineral and Petroleum Titles of the Minerals Management Division by the author, who works out of the regional office in Stellarton, Pictou County. Regional Geologists of the Regional Services Branch offices in Coxheath (Don MacNeil), Truro (Donald Weir) and Bridgewater (Sandra Johnson) assist in monitoring mineral exploration activity in their respective regions.

The monitoring process covers exploration activities throughout Nova Scotia and consists of visits to company offices and exploration sites, liaison with industry personnel, and the review of current assessment reports and other material submitted by industry. Liaison with industry allows the department to maintain an awareness of current exploration activities throughout the province. Assistance or advice is provided as necessary, and any drill core generated by mineral exploration activity in the province is recorded as part of the monitoring process. This core may be recovered for archiving in the Drill Core Library in Stellarton when no longer required by the companies.

The Exploration Monitoring geologist is also responsible for auditing confidential assessment reports that are submitted in support of the renewal of exploration licences. In 2002, 102 assessment reports were received and audited for compliance with the Mineral Resources Regulations.

Mineral Exploration Activity in 2002

During 2002 mineral exploration in Nova Scotia continued at approximately the same level of activity as in the previous three years. The general level of field exploration expenditures has continued to decline over the past three years, however, with field expenditures expected to be in the range of $1.8-2.0 million for 2002, compared with $2.9 million in 2001, and $3.5 million in 2000 (Table 1, Fig. 1). Exploration was focused primarily on industrial minerals and gold, with very little activity for base metals. In this regard, interest in the exploration and development of industrial mineral commodities has strengthened in recent years, whereas activities related to the exploration and development of base metals and gold has declined over the same period due primarily to low commodity prices for metals and the difficulty in raising venture capital to fund exploration programs. The general outlook for gold exploration, however, is showing indications for improvement as the price of gold has strengthened significantly, along with a renewed interest in a number of gold properties hosted by the lower Paleozoic metasediments of the Meguma Group.

Preliminary figures for the total number of general claims staked in 2002 show an increase of 43% from the previous year to 12,050 (Table 1, Fig. 2). 12,780 claims for all commodities were in effect at the end of 2002, represented by 509 general and special licences covering an area of 206,882 ha or 2,068 km^2, approximately 3.8% of the total area of the province. The amount of exploration drilling continued to be low in comparison to previous years with a preliminary estimate of 5000 m in 2002 compared with 5100 m in 2001 and 8500 m in 2000.

Approximately 187 companies and individuals held exploration interests (licences or options) in the province in 2002, including 5 major, 10 junior and 45 private companies (Tables 2, 3 and 4). In addition, several mining lease holders carried out exploration and development work on leases or on unclaimed ground where these commodities did not require licences (e.g. limestone, gypsum). Organizations actively engaged in exploration during 2002 included 5 junior and 15 private companies (Fig. 3, Table 5), as well as a number of individuals.

McCulloch, P. D. 2003: *in* Mineral Resources Branch, Report of Activities 2002; Nova Scotia Department of Natural Resources, Report 2003-1, p. 91-101.

Table 1. Details of exploration and development activity in Nova Scotia, 1993-2002.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002[p]
Total Field Exploration Expenditures ($)	2 300 000	1 400 000	2 843 000	5 752 000	6 700 000	5 600 000	3 800 000	3 500 000	2 900 000	2 000 000
Total Licences Issued (all categories)	593	673	698	1 127	978	711	707	606	498	509
Claims in Good Standing (new and reissued)										
General	9 504	13 740	15 861	33 399	25 190	11 452	14 045	10 951	8 391	12 050
Special (Order in Council)										
Salt and Potash	66	66	-	214	214	820	804	255	255	255
Coal	433	218	218	311	240	253	173	-	-	-
Geothermal	-	158	158	158	158	158	158	158	158	158
Underground Gas Storage	-	-	-	-	-	106	106	106	307	307
Tailings	146	146	146	146	146	-	-	-	-	-
Other (gold, base metals)	452	255	130	130	130	130	132	10	10	10
Uranium*	(226)	(226)	(226)	(226)	(226)	(226)	(226)	(226)	(226)	(226)
Total (excluding closures and uranium licences)	10 601	14 583	16 513	34 358	26 078	12 219	15 418	11 480	9 121	12 780
Total Area Held Under Licence										
(ha)	171 609	236 069	267 312	556 186	422 150	209 132	249 586	185 838	147 650	206 882
(acres)	424 040	583 320	660 520	1 374 320	1 043 120	516 760	616 720	459 200	364 840	511 200
Work Reported for Licence Renewals ($)	983 402	1 694 368	1 601 639	2 376 023	3 146 899	5 385 194	2 969 047	1 136 304	2 811 393	1 457 012
Number of Assessment Reports Received	62	84	111	108	133	134	100	85	72	102

[p]preliminary
*parentheses around uranium claims indicate ground alienation due to the uranium moratorium

December 31, 2002

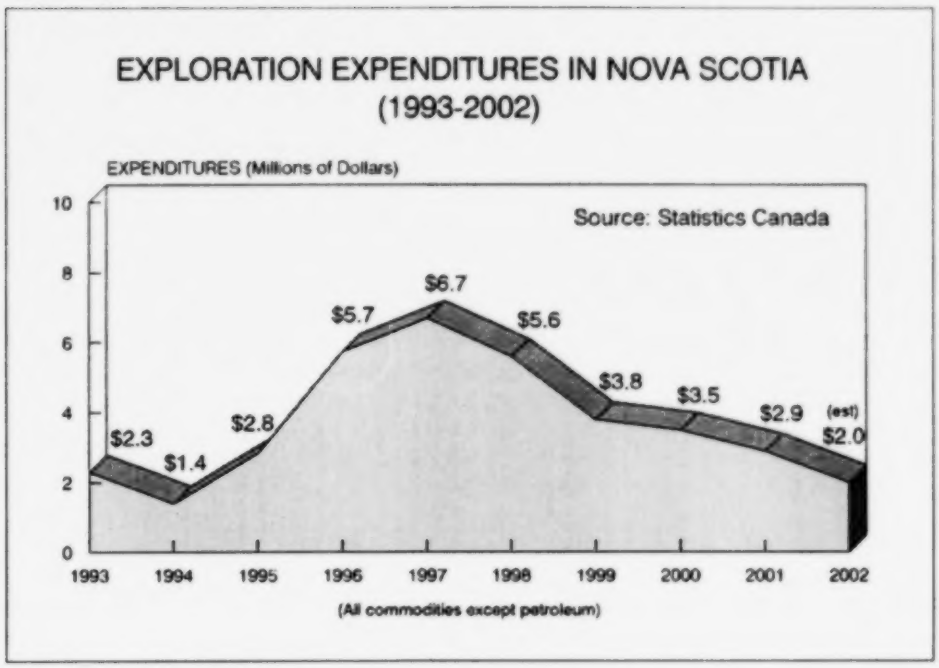


Figure 1. Exploration expenditures in Nova Scotia, 1993-2002.

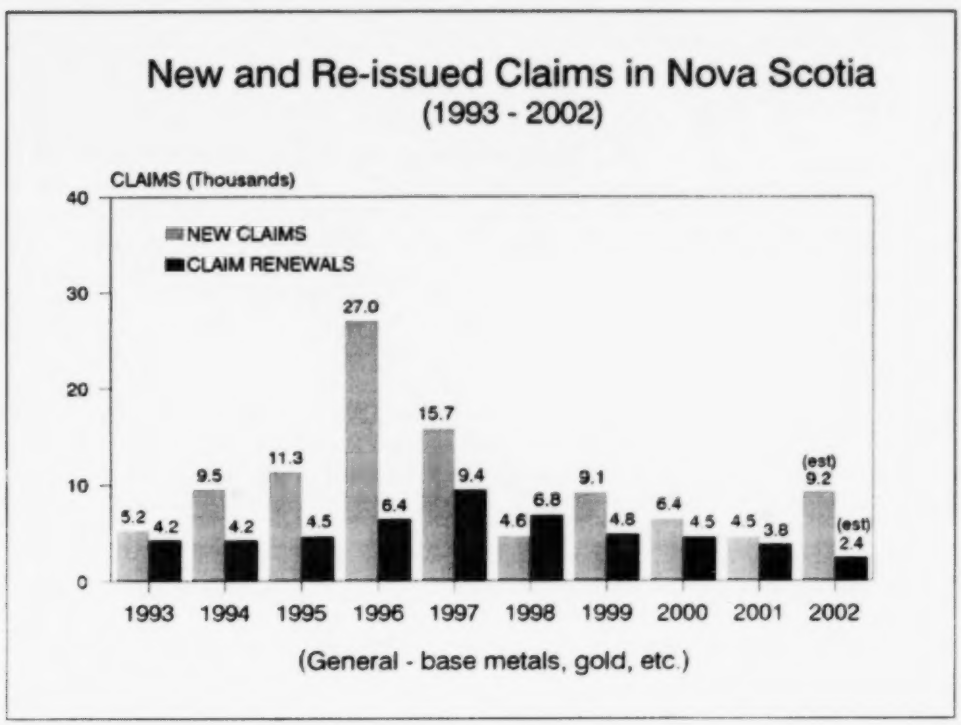


Figure 2. Claim staking in Nova Scotia, 1993-2002.

Table 2. Major companies with exploration interests (licences or options) in Nova Scotia.

	2000	2001	2002	Office location in 2002
Aur Resources Incorporated			-	
Lafarge Canada Incorporated	x	x	-	Brookfield
Noranda Exploration Company Limited	-			
Pasminco Resources Canada Company (formerly Savage Resources Canada Limited)	x	x	-	
Statia Terminals Canada Limited	x	x	-	
W. M. C. International Limited	-	-	-	

x indicates work performed
- company inactive
blanks indicate that the company did not hold an exploration licence in that particular year

Industrial Minerals

Exploration and development work for industrial minerals was undertaken for a number of commodities including kaolin, silica sand, titanium, barite, limestone, gypsum, aggregate resources and building stone.

Black Bull Resources Incorporated continued a detailed exploration and development program for silica in an altered quartz-kaolinite breccia zone along the Tobeatic Shear Zone in the Flintstone Rock area, Yarmouth County. The company completed additional diamond-drilling in the immediate vicinity of the proposed open pit operation during the year. Black Bull was recently given environmental approval for its proposed development plans.

Titanium Corporation Incorporated continued a detailed evaluation of the titanium-bearing heavy mineral sands along the Shubenacadie River near Maitland, Hants County. The company completed additional drilling at several locations along the river between Maitland and Admiral Rock, as well as locations along the Cobequid Bay. The company also completed additional bulk sampling of the titanium-bearing sands along the Shubenacadie River. Dr. Martin Roche completed additional heavy mineral analyses of sand samples from titanium-bearing sand deposits in the central area of Cobequid Bay, and an associated company, Hansone Limited, completed additional heavy mineral analyses of sand samples taken from the Avon River and the Kennetcook River near Windsor, Hants County.

Glencoe Resources Incorporated completed additional work on the Glendale limestone deposit near River Denys, Inverness County, consisting of diamond-drilling and rock sampling. The company is continuing an evaluation of Precambrian dolomitic marble of the Blues Brook Formation (part of the George River Metamorphic Suite) for both dimension stone and for fillers and coaters. Robert MacDonald also carried out an evaluation of Precambrian dolomitic marble of the Blues Brook Formation near Churchview, Inverness County, during the year, consisting of prospecting and rock sampling. Anthony Barrett also continued an evaluation of Precambrian dolomitic marble of the George River Metamorphic Suite near New Campbellton, Victoria County, consisting of prospecting and rock sampling.

MacLeod Resources Limited began an evaluation of the building stone potential of variably coloured dolomitic marble of the Precambrian George River Metamorphic Suite in the MacLean Road area east of Creignish, Inverness County. Preliminary work on the property consisted of reconnaissance geological mapping, rock sampling and the extraction of test block material. Lynx Minerals Incorporated carried out prospecting, geological mapping and additional soil geochemical sampling to evaluate the potential

Table 3. Junior exploration companies in Nova Scotia.

	2000	2001	2002	Office location in 2002
Aurogin Resources Limited			x	
Black Bull Resources Incorporated	x	x	x	
C_2C Mining Corporation	x	x	-	Kentville
Corner Bay Minerals Incorporated	-	-	--	
Exploration Orex Incorporated	-	-		
Globex Mining Enterprises Incorporated	-	-	x	
Heartland Resources Limited	-	-	-	Dartmouth
Newfoundland Goldbar Resources Incorporated			-	
Regal Goldfields Limited	-	-	-	
Roycefield Resources Limited	-			
RJZ Mining Incorporated	-	-	x	
Titanium Corporation Incorporated (formerly Titanium Corporation of Canada Limited)	x	x	x	

x indicates work performed
- inactive
blanks indicate that the company did not hold an exploration license in that particular year

for additional barite mineralization immediately north of the Peter Campbell mine property near Scotsville, Inverness County.

Champlain Resources Incorporated initiated a detailed exploration program in the Brazil Lake area, Yarmouth County, to evaluate the Brazil Lake pegmatite occurrences for both industrial mineral commodities as well as for associated base metals. The company carried out detailed prospecting and rock sampling in the Deerfield and Brazil Lake areas and completed a preliminary diamond-drilling program at Brazil Lake during the year.

Gold

Exploration for gold continued at approximately the same level of activity as in the previous two years. The lower Paleozoic Meguma Group of southern mainland Nova Scotia continued to be the principal focus for gold exploration in the province, and was also the focus of heightened staking by several companies and private interests during the year.

Exploration for gold was undertaken on several properties in the lower Paleozoic Meguma Group of southern mainland Nova Scotia. 37797751 Canada Incorporated recently acquired the former Coxheath Gold Holdings property at Tangier, Halifax County, to determine the feasibility of re-opening the mine. The company carried out diamond-drilling on the property in late 2001 and completed detailed drill core analyses on the core early in 2002.

Aurogin Resources Limited completed preliminary diamond-drilling, geochemical studies, and metallurgical work on the Moose River gold property, Halifax County, during the year. The company has formalized an agreement with Moose River Resources Incorporated to continue a detailed evaluation of the Touquoy deposit, including the Main Zone and the East Zone, which hosts published reserves of 3.8 million tonnes indicated, grading 2.22 g/t gold. Globex Mining Enterprises Incorporated carried out prospecting and rock sampling on the Mooseland gold property, Halifax County. The company optioned the property to Azure Resources Corporation in September, 2002. Azure plans to carry out a preliminary diamond-drilling program on the property in 2003 to evaluate the results from previous drilling programs.

Strikezone Minerals (Canada) Limited, in an option agreement with Ellsin Resources Incorporated, completed a soil geochemical survey

Table 4. Private exploration companies in Nova Scotia.

	2000	2001	2002	Office location in 2002
166881 Canada Incorporated	-	-	-	
3779751 Canada Incorporated	-	-	x	
Alva Construction Limited			-	
Atlantic Industrial Minerals Limited	-	-		
Asedex Minerals Corporation Limited	-	x	-	
Aurion Minerals Limited	-	-	-	
Broad River Exploration	-			
Burnt Point Resources Incorporated	-	-	-	Halifax
Candor Ventures Corporation			x	
Cannova Goldfields Incorporated	-	-	-	
Cape Minerals Limited	-	-		
Champlain Resources Incorporated	-	-	x	
Cobequid Life Sciences Limited	-	-		
Conrad Brothers Limited	-	-	x	Dartmouth
D&D Metal Detectors Limited	-			
D. R. Duncan & Associates Limited	-			
Datum Quest Explorations	-		-	
Dufferin Resources Incorporated	x	x	-	Halifax
Earth Search Sciences, Incorporated	-	-		
Ellsin Resources Incorporated	x	x	x	
Elmsdale Landscaping Limited		-	-	
Emerald Isle Resources Incorporated		-	x	
Gallant Aggregates Limited	-	-	-	
Gammon Lake Resources Incorporated	-	-	-	Halifax
Geocol Mining & Exploration	-			
Geosearch	x	-	-	Sackville
Geostorage Associates	x	x	x	Halifax
Giant Meguma Holdings	-			Halifax
Glencoe Resources Incorporated	x	-	x	
Gold 'n' Crystal Minerals	x	-	x	East Advocate
Golden Ace Mineral Explorations Limited	x	-	-	
Goliath Copperfields Limited	x	-		
H & E Mullen Investments Limited	x	-	-	
Hansone Limited	x	x	x	
Hibernia Minerals Incorporated	-			
Highland Range Minerals Limited	-	-	-	
Huntington Explorations Incorporated	-	-	-	
Intragaz & Company Limited Partnership	-	x	x	
John Logan Enterprises Limited	-	-	-	
Jubilee Minerals	-	-	x	Bedford
KaoClay Resources Incorporated	x	-	-	Milford Station
Kelly Investments Limited	-	-		
Kelly Rock Limited	-		-	Sydney
Little Lake Gold Mines Limited	-			Dartmouth
Lynx Minerals Corporation	x	-	-	
MacLeod Resources Limited	x	x	x	
Maritime Mica Incorporated	-	-	-	

Table 4. Continued.

	2000	2001	2002	Office location in 2002
Meguma Resource Enterprises Incorporated			x	
Mercator Geological Services Limited	-			Dartmouth
Minas Basin Pulp & Paper Company Limited	-	-	-	
Mineral City Enterprises Incorporated	-	-		
Mount Cameron Minerals Incorporated	-	-	-	
North Cape Breton Resources Limited	-	-		
Nycon Resources Incorporated		-	x	
Oceanview Minerals Limited		-	-	
Ochter Holdings Limited	-			
Pan East Petroleum Corporation (formerly Pan East Resources Incorporated)	-	-	-	
Prodigy Resources Incorporated	-	-		
Rainbow Resources Limited	-	-	-	Dartmouth
Remoscan Limited	-			
Robert Stewart-Patterson & Associates		-	-	
The Shaw Group Limited (formerly L. E. Shaw Limited)	x	x	-	Lantz
Tangier Limited Partnership (formerly Tangier Mining Incorporated)	-			
Tri-Explorations Limited				
True Metallic Explorations	x	x	-	Bedford
Uravan Minerals Incorporated	-			
Votix Corporation Limited	x	-	-	Trenton

x indicates work performed
- inactive
blanks indicate that the company did not hold an exploration license in that particular year

on the Lake Charlotte gold property, Halifax County, and RJZ Mining Incorporated completed an assessment of previous aeromagnetic data on the Beaver Dam property, Halifax County. Conrad Brothers Limited completed a small diamond-drilling program in the vicinity of their quarry operations at Montague Gold Mines, Halifax County, and Nycon Resources Incorporated completed a reconnaissance soil geochemical survey along the southern extension of the Salmon River anticline on the company's Muskrat Lake property, Halifax County.

A number of small exploration programs were also completed on several properties throughout the Meguma Group by several individuals and private interests. Dennis Forgeron completed a preliminary assessment of the Country Harbour gold property, Guysborough County, consisting of prospecting and a detailed geological compilation of the property. Scott Grant carried out rock sampling and analytical work on the Cochrane Hill gold property in Guysborough County in the immediate vicinity of the former Northumberland Mines property. Gold 'n Crystal Minerals carried out prospecting and rock sampling on the North Star gold mine property at Isaacs Harbour, Guysborough County. Meguma Resource Enterprises Incorporated continued prospecting and related activities on the Miller Lake gold property in Guysborough County and the Ecum Secum and Fifteen Mile Stream gold properties in Halifax County.

Base Metals

Exploration for base metals continued at approximately the same level of activity as in the previous two years and was focussed primarily on

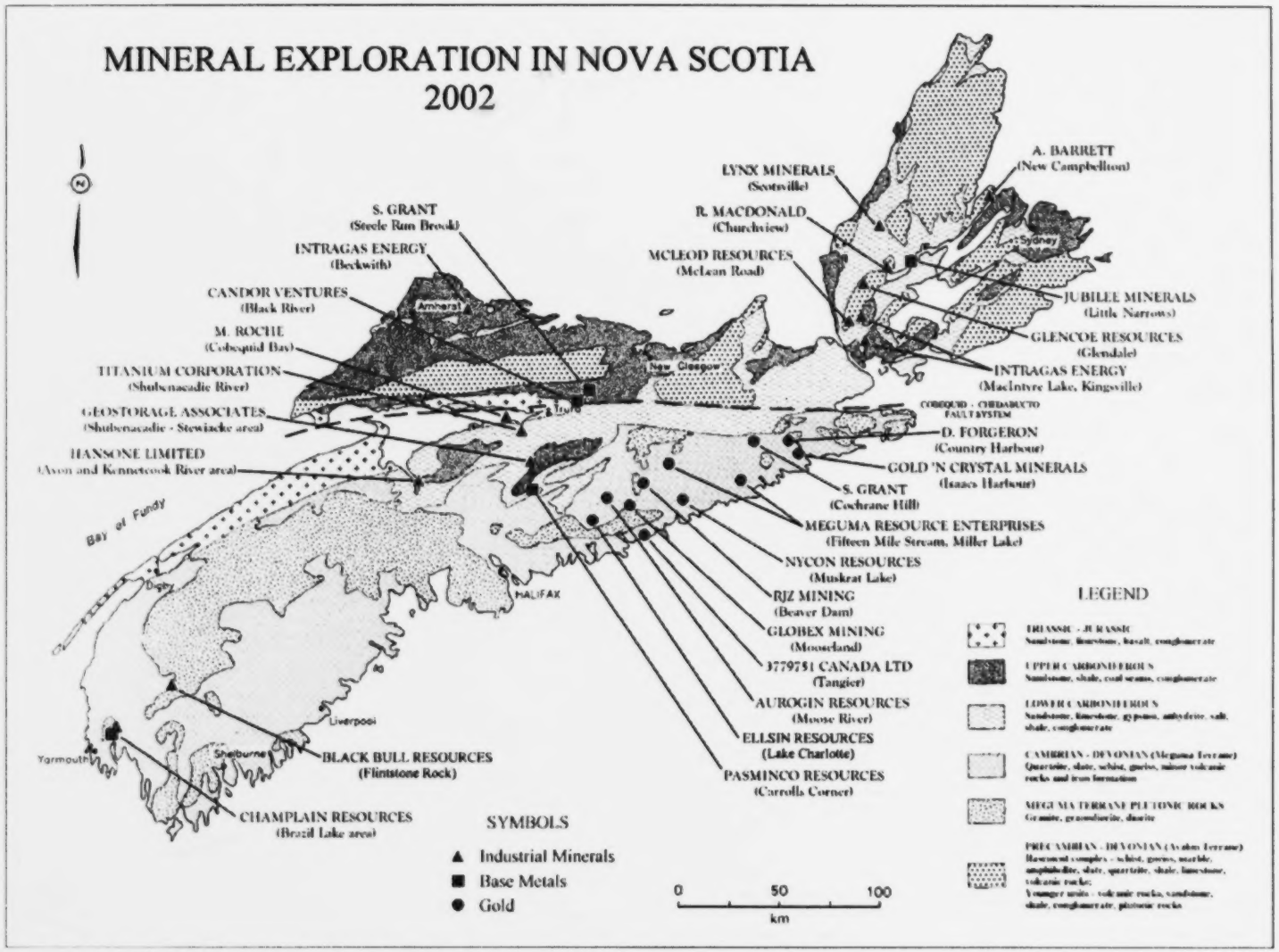


Figure 3. Mineral exploration programs in Nova Scotia, 2002.

Table 5. Excploration programs in Nova Scotia, 2002.

COMPANY/INDIVIDUAL	LOCATION	COMMODITY	PROGRAM
3779751 Canada Limited	Tangier, Halifax County	Gold	Drill-core analyses
Aurogin Resources Limited	Moose River, Halifax County	Gold	Diamond-drilling, metallurgical testing
A. Barrett	New Campbellton, Victoria County	Marble	Prospecting, rock sampling
Black Bull Resources Incorporated	Flintstone Rock, Yarmouth County	Kaolin, silica sand	Diamond-drilling
Candor Ventures Corporation	Black River, Colchester County	Base and precious metals	Ground geophics
Champlain Resources Incorporated	Brazil Lake, Yarmouth County	Industrial minerals, base metals	Prospecting, rock sampling, diamond-drilling
Conrad Brothers Limited	Montague Gold Mines, Halifax County	Gold	Diamond-drilling
D. Forgeron	Country Harbour, Guysborough County	Gold	Prospecting
Geostorage Associates	Shubenacadie area, Colchester County	Salt (underground storage)	2D seismic survey
Glencoe Resources Incorporated	Glendale, Inverness County	Marble	Diamond drilling, rock sampling
Globex Mining Enterprises Incorporated	Mooseland, Halifax County	Gold	Prospecting, rock sampling
Gold 'n Crystal Minerals	Isaacs Harbour, Guysborough County	Gold	Prospecting, rock sampling
Jubilee Minerals Limited	Bucklaw, Victoria County	Base metals	Prospecting, geological mapping, magnetometer survey
Intragaz and Co. Limited Partnership	Kingsville area, Inverness County McIntyre Lake, Inverness County Beckwith, Cumberland County	Salt (underground storage)	Evaluation of previous drilling
Lynx Minerals Incorporated	Scotsville, Inverness County	Barite	Prospecting, geological mapping
MacLeod Resources Limited	MacLean Road, Inverness County	Marble	Prospecting, geological mapping, soil sampling
Martin Roche/Hansone Limited	Cobequid Bay Avon River/Kennetcook River, Hants County	Mineral sands (titanium) Mineral sands (titanium)	Heavy mineral analyses Heavy mineral analyses
Meguma Resource Enterprise Inc.	Miller Lake, Guysborough County Fifteen Mile Stream, Halifax County Ecum Secum, Halifax County	Gold	Prospecting
Monster Copper Resources Incorporated	Central mainland Nova Scotia	Base and precious metals	Reconnaissance geological mapping, ground geophysics

Table 5. continued.

COMPANY/INDIVIDUAL	LOCATION	COMMODITY	PROGRAM
Nycon Resources Incorporated	Muskrat Lake, Halifax County	Gold	Soil geochemical sampling
R. MacDonald	Churchview, Inverness County	Marble	Prospecting, rock sampling
Pasminco Resources Canada Company	Carrolls Corner area, Halifax County	Base metals	Prospecting, geological mapping
RJZ Mining Incorporated	Beaver Dam, Halifax County	Gold	Review of previous geophysical data
S. Grant	Cochrane Hill, Guysborough County Steele Run Brook, Colchester County	Gold Base metals	Rock sampling Geological mapping, magnetometer survey
Strikezone Minerals (Canada) Limited	Lake Charlotte, Halifax County	Gold	Soil geochemical sampling
Titanium Corporation Incorporated	Shubenacadie River, Hants County	Mineral sands (titanium)	Drilling, bulk sampling

areas of known mineral occurrences in the northern and western areas of mainland Nova Scotia.

Jubilee Minerals Limited carried out a preliminary exploration program in the Little Narrows area south of Bucklaw, Victoria County, to evaluate the base metal potential of the Lower Carboniferous Windsor Group immediately northeast of the company's Jubilee Pb-Zn property at Little Narrows. Work on the property included prospecting, geological mapping and a magnetometer survey. Pasminco Resources Canada Limited carried out prospecting and geological mapping in the vicinity of Carrolls Corner, Halifax County, to evaluate the potential for additional Pb-Zn reserves in the Lower Carboniferous sediments of the Windsor Group west of the Gays River Pb-Zn deposit.

Monster Copper Resources Incorporated initiated an exploration program to evaluate the base and precious metal potential of several properties along the Cobequid-Chedabucto Fault Zone in central mainland Nova Scotia. The company completed reconnaissance geological mapping and geophysical work during the year. Candor Ventures Corporation conducted reconnaissance geophysical work in the Black River area near Riversdale, Colchester County, to evaluate the base and precious metal potential along the east-west trending Cobequid-Chedabucto Fault zone. Scott Grant completed reconnaissance geological mapping and a magnetometer survey to evaluate the base and precious metal potential of the Steele Run Brook area west of the Mount Thom Cu-Co prospect.

Other

Intragas Energy Limited Partnership continued an evaluation of the potential for developing underground bulk hydrocarbon storage in the extensive salt deposits in the Lower Carboniferous sediments of the Windsor Group in the Kingsville and McIntyre Lake areas, Inverness County, and in the Beckwith area, Cumberland County. Recent work consisted of an evaluation of previous drilling results in the three areas including core logging and drill core sampling.

Geostorage Associates continued a detailed evaluation of the potential for developing underground bulk storage of hydrocarbons in the Lower Windsor salt deposits underlying the Shubenacadie-Stewiacke area of central mainland Nova Scotia. The company completed a 2D seismic survey during the year in the area east of the Shubenacadie River between the villages of Shubenacadie and Stewiacke.

Mesozoic-Cenozoic Stratigraphy of the Lowlands of Southwest Cape Breton Island (NTS 11F/11, 11F/14)[1]

R. R. Stea, S. E. Pullan[2] and M. Feetham

Introduction

The Mesozoic-Cenozoic stratigraphy of the lowlands of southwestern Cape Breton Island records the history of formation of the present landscape. Unconsolidated surficial deposits that make up the present valley fill range in age from Early Cretaceous to recent. The greatest thickness of sediment was deposited in a succession of glacial lakes that filled valleys at various times during the Wisconsinan glaciation. In the River Denys Basin as much as 50 m of fine-grained silty clay was deposited. The purpose of this paper is to describe the deposits in their stratigraphic context, interpret the environments of deposition, and reconstruct the ice sheets that produced the deposits.

The project is part of the Targeted Geoscience Initiative (TGI), jointly funded through the Geological Survey of Canada (GSC) and the Nova Scotia Department of Natural Resources (NSDNR), and aimed at stimulating mineral resource development in Cape Breton Island. The main goal of the project is to broaden geoscience knowledge in the area, with a focus on the economic potential of Carboniferous bedrock and the overlying Mesozoic and Cenozoic sediments. Of particular interest is the search for hidden outliers of Mesozoic sediments, including valuable kaolin and silica sand, preserved in fault-bound basins and obscured by Quaternary cover (Stea and Pullan, 2001). This report will summarize the results from drilling and seismic surveys conducted during 2000 and 2001.

Physiography and General Geology

The study area can be divided into two major lowland basins flanked on either side by highland areas (Fig. 1). Creignish Hills and North Mountain are upland massifs composed of igneous and metamorphic rocks ranging in age from Proterozoic to lower Devonian (Kelley, 1967; Lynch and Brisson, 1996). The lowland areas are defined as the River Denys Basin (Kelley, 1967) and the River Inhabitants Lowland (this study), separated from each other by an intermediate upland area underlain by Mabou Group clastic rocks termed the Maple Brook Syncline (Kelley, 1967). The River Denys Basin is a broad and rolling lowland plain to the north of the Maple Brook syncline, underlain primarily by clastic and evaporitic rocks of the Windsor Group. Inset in the River Denys Basin in the vicinity of River Denys Centre is a flatter and lower region of nearly rectangular shape which will be called the Big Marsh lowland (Fig. 1). The River Inhabitants Lowland is a north-south basin which encloses the floodplain of the River Inhabitants (Grant, 1994).

Methods

Mapping and Stratigraphic Studies

Road, stream and coastline traverses were conducted to describe and classify the various types of surficial sediments in the map area. Surficial

[1]Funded by Natural Resources Canada and the Nova Scotia Department of Natural Resources under the Targeted Geoscience Initiative project: Geological Mapping for Mineral Development in South-central Cape Breton Island
[2]Geological Survey of Canada, Terrain Sciences Division, 601 Booth Street, Ottawa, Ontario K1A 0E8

Stea, R. R., Pullan, S. E. and Feetham, M. 2003: *in* Mineral Resources Branch, Report of Activities 2002; Nova Scotia Department of Natural Resources, Report 2003-1, p. 103-126.

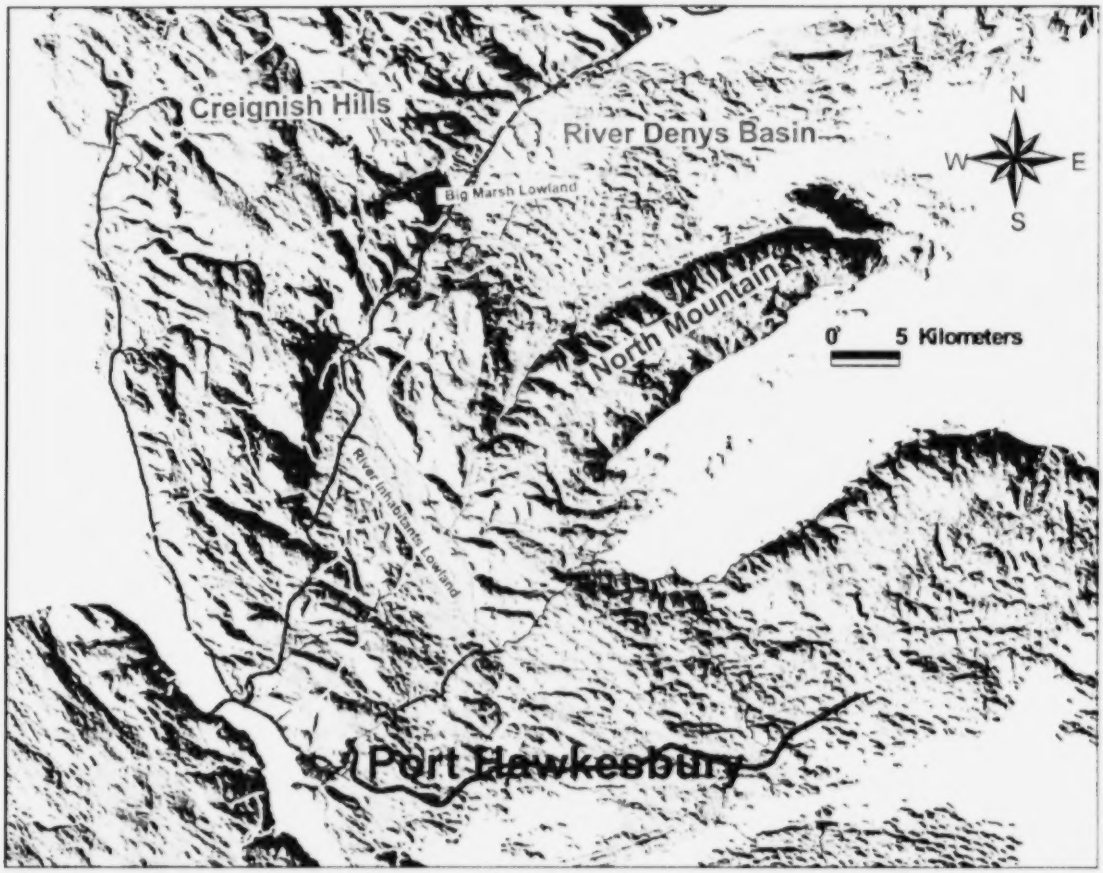
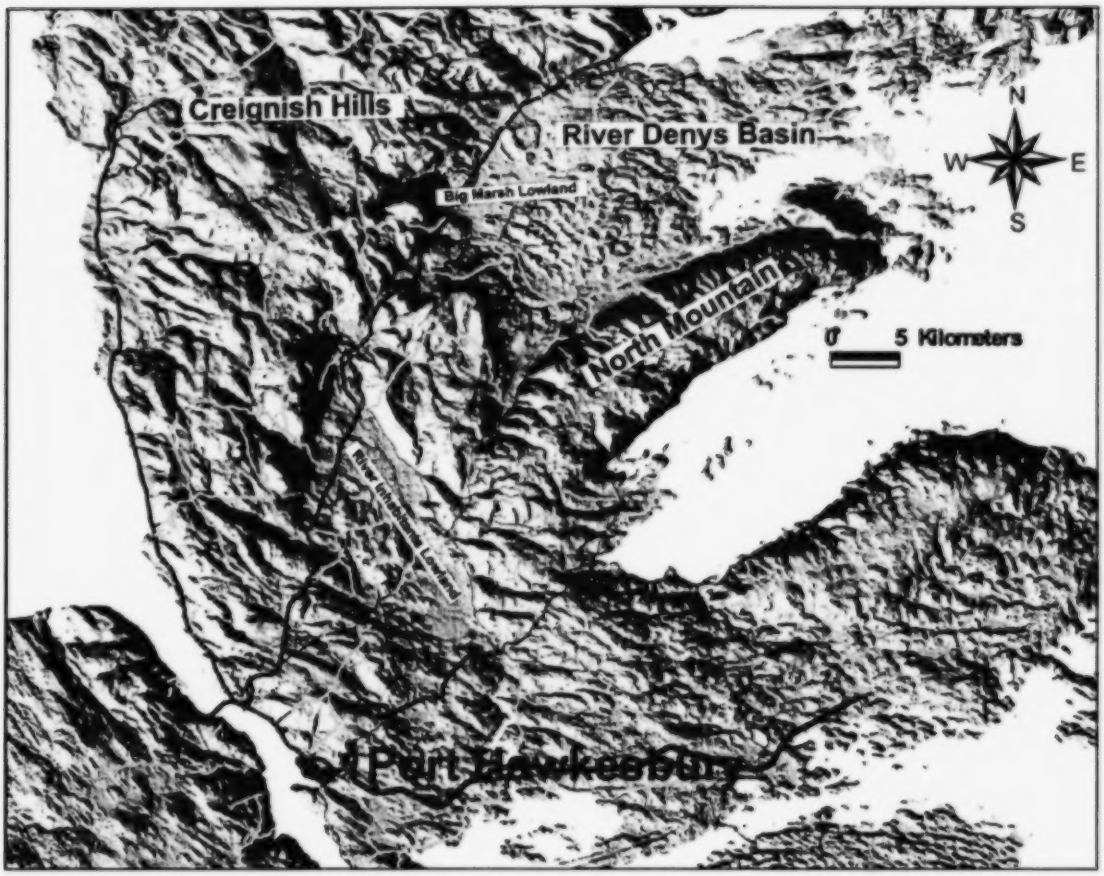


Figure 1. Physiography and location of the study regions of the Targeted Geoscience Initiative (TGI), Southwest Cape Breton Island.

units were delineated by matching the surficial deposits (e.g. till, fluvial, and colluvial deposits) with identifiable landforms traceable on air photographs and on digital terrain models. These data were integrated with other data sources (previous maps, well log data, etc.) in a GIS platform for final map production. Detailed stratigraphic sections were measured on coastline, road and stream exposures, and in the recently opened Sugar Camp quarry. Till fabric measurements were conducted using a standard methodology (e.g. Evenson, 1971) with the bearing and plunge of the long axes of 30-50 pebbles measured and plotted on a Schmidt net. Stratigraphic logs of all measured sections were constructed using LOGPLOT 98.

Drilling

The drilling methodology was similar to that undertaken in the Musquodoboit Valley, which defined large areas of previously unknown Mesozoic silica sand and kaolin clay (Finck *et al.*, 1995; Gillis, 1998). For the first phase of drilling (March 2001) a large track-mounted drill equipped with a wire line coring system was used. It was designed to give high recovery in unconsolidated sand and clay, and was extremely mobile. Materials could be quickly triconed if core was not desired. In the fall of 2001 a second phase of drilling was conducted using a smaller, more versatile, track-mounted rotary drill. This multi-purpose drill allowed for a variety of sampling techniques



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units were delineated by matching the surficial deposits (e.g. till, fluvial, and colluvial deposits) with identifiable landforms traceable on air photographs and on digital terrain models. These data were integrated with other data sources (previous maps, well log data, etc.) in a GIS platform for final map production. Detailed stratigraphic sections were measured on coastline, road and stream exposures, and in the recently opened Sugar Camp quarry. Till fabric measurements were conducted using a standard methodology (e.g. Evenson, 1971) with the bearing and plunge of the long axes of 30-50 pebbles measured and plotted on a Schmidt net. Stratigraphic logs of all measured sections were constructed using LOGPLOT 98.

Drilling

The drilling methodology was similar to that undertaken in the Musquodoboit Valley, which defined large areas of previously unknown Mesozoic silica sand and kaolin clay (Finck *et al.*, 1995; Gillis, 1998). For the first phase of drilling (March 2001) a large track-mounted drill equipped with a wire line coring system was used. It was designed to give high recovery in unconsolidated sand and clay, and was extremely mobile. Materials could be quickly triconed if core was not desired. In the fall of 2001 a second phase of drilling was conducted using a smaller, more versatile, track-mounted rotary drill. This multi-purpose drill allowed for a variety of sampling techniques

including augering, split spooning and coring. Standard augers with a 4.5 inch diameter could be used to quickly drill down through surface clay, sand, and gravel. Grab samples could be taken at 5-foot intervals along each auger. Alternatively, a 1.5-inch diameter, 2 foot long split spoon sample could be obtained by driving a sampler ahead of the auger at the base of the hole. The drill was equipped with a 140 lb. hammer with a 30-inch drop. If ground conditions became unfavourable for auguring or split spooning, the drill was switched to diamond drilling. Cored holes were cased with 3.9 inch HW steel pipe to prevent caving. A HQ core barrel and rods were used to obtain a 2.5-inch core sample. All holes were drilled vertically, and the steel casing was removed upon completion.

Down-hole Geophysics

An extensive suite of downhole geophysical logs has been acquired in eight of the boreholes drilled in 2001. These boreholes were cased with PVC pipe (6-7.5 cm inner diameter) to preserve borehole access and to permit downhole electrical/magnetic geophysical logging. The data set includes natural gamma, inductive conductivity, and magnetic susceptibility logs acquired using a Geonics EM-39. Further information on this instrumentation and the resulting geophysical logs may be found at http://sts.gsc.nrcan.gc.ca/clf/borehole_geophysic.asp or in Douma *et al.* (1999).

The natural gamma, conductivity and magnetic susceptibility logs are very useful in identifying varying lithologies downhole. The logs provide a qualitative estimate of grain size and allow the identification of geophysical signatures that can be used for hole-to-hole or regional correlations. In most sedimentary environments, high natural gamma count rates are associated with fine-grained units such as silt and clay, whereas low count rates are associated with sand and gravel. The conductivity of a porous, unconsolidated material is a function of the combined electrical conductivity of the sediment and the pore fluid, and high conductivities (in the 100s of mS/m) are typically an indication of highly conductive (e.g. saline) porewater. Magnetic susceptibility is a dimensionless measure of the magnetization capacity of a material, and in unconsolidated earth materials most of the response results from small quantities of magnetite. Hence, anomalously large values of bulk magnetic susceptibility in a formation are an indirect indication of increased heavy mineral content.

Lithostratigraphy of the River Denys Basin

Based on previous seismic reflection testing (Pullan *et al.*, 2001), eight holes were drilled in the southwest part of the River Denys Basin (Fig. 2) where surficial cover is commonly thick (up to >100 m). Areas of special interest are the Big Marsh lowlands and the western River Denys Basin margin. A generalized stratigraphic profile from northwest to southeast across the Big Marsh lowlands can be constructed using logs from drillholes URD-01, -02, MPR-01-1, and BM-01-1, -2, and -3 (Figs. 2, 3). The Big Brook quarry in the River Denys Basin provides another reference section for the region, where radiocarbon dating of interglacial and interstadial organic beds provides temporal control for the lithostratigraphic units (Fig. 4). The surficial units are described from the base or bedrock contact to the top.

Bedrock and Breccias

Coarse-grained grey-white gypsum of the Windsor Group was encountered at the base of holes URD-01-1, MPR-01-1, BM-01-2, and BM-01-3 at depths of 80.8 m, 59.4 m, 56.3 m and 19.5 m, respectively. Gypsum texture ranges from massive mosaic to slightly nodular, commonly grading into a gypsum breccia infilled with grey clay. Steeply, dipping bands of black-brown carbonate are also evident in the drill core. Hole BM-01-1 bottomed in grey-white limestone at 92.2 m. Lying above competent bedrock in the deeper part of the basin (BM-01-1) is a series of alternating blue-grey and red-brown, strongly calcareous mudstones and breccias up to 20 m in thickness (interpreted as part of the Windsor Group).

Lower Till

Drag line trenches in the Big Brook gypsum quarry (Fig. 2) revealed a complex Quaternary

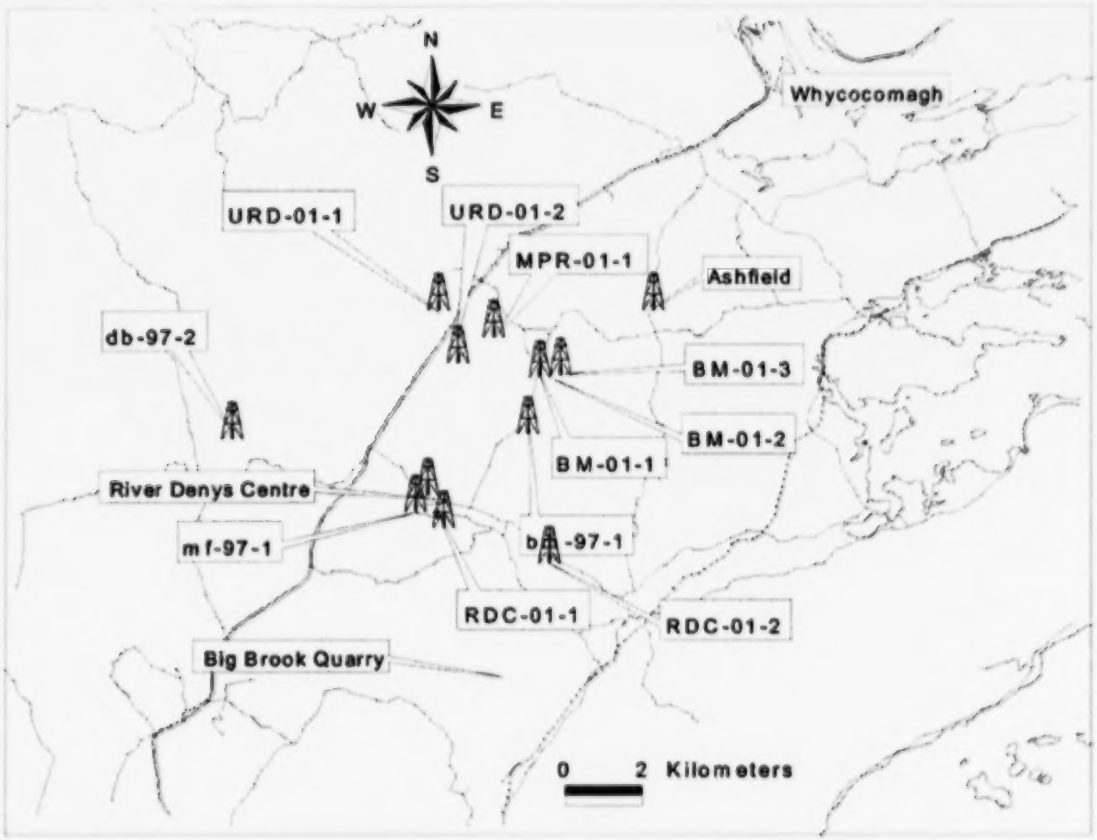

Figure 2. Location of reference sections and TGI diamond-drill holes in the River Denys Basin. Diamond-drill hole DB-97-2, at Diogenes (Grant) Brook encountered ~50 m of Early Cretaceous sediments.

stratigraphy, with an oxidized, greenish-grey silty till unit at the base, overlying the gypsum bedrock surface (Fig. 4). Large spruce wood fragments were found embedded in the grey lower till, providing radiocarbon dates of >49,000 (GSC-3289) and >52,000 (GSC-3880) yr B.P. Pollen from a levels organic layer sheared into the lower till was characterized by high of *Picea* (Spruce), *Alnus*, (alder) and fern spores, a boreal-forest type assemblage (R. J. Mott, unpublished palynological report 81-6). A mid-Wisconsinan date of 36,200±1280 yr B P (GSC-3206) was obtained from organic silt in a solution cavity beneath the lower till, but with a similar palynological signature (R. J. Mott, unpublished palynological report 80-12). The date is thought to be contaminated by "young carbon" (Mott and Grant, 1985), because it is apparently lower in stratigraphic position than the wood pieces dated as infinite in age. The wood fragments could either be inherited from an interglacial soil beneath the Lower Till or sheared into the unit from a younger soil by overriding ice. The later hypothesis is more likely as the Richmond Till was observed to intrude the lower till in large "till wedges". Interglacial wood from Nova Scotia at many localities dated by U-series disequilibrium methods did not produce ages in excess of 140 ka (de Vernal *et al.*, 1986). It is interesting to note that an undated organic silt just below the Richmond Till (Fig. 4) had a pollen profile significantly different than the lower sink-hole organics (R. J. Mott, unpublished palynological report 84-12).

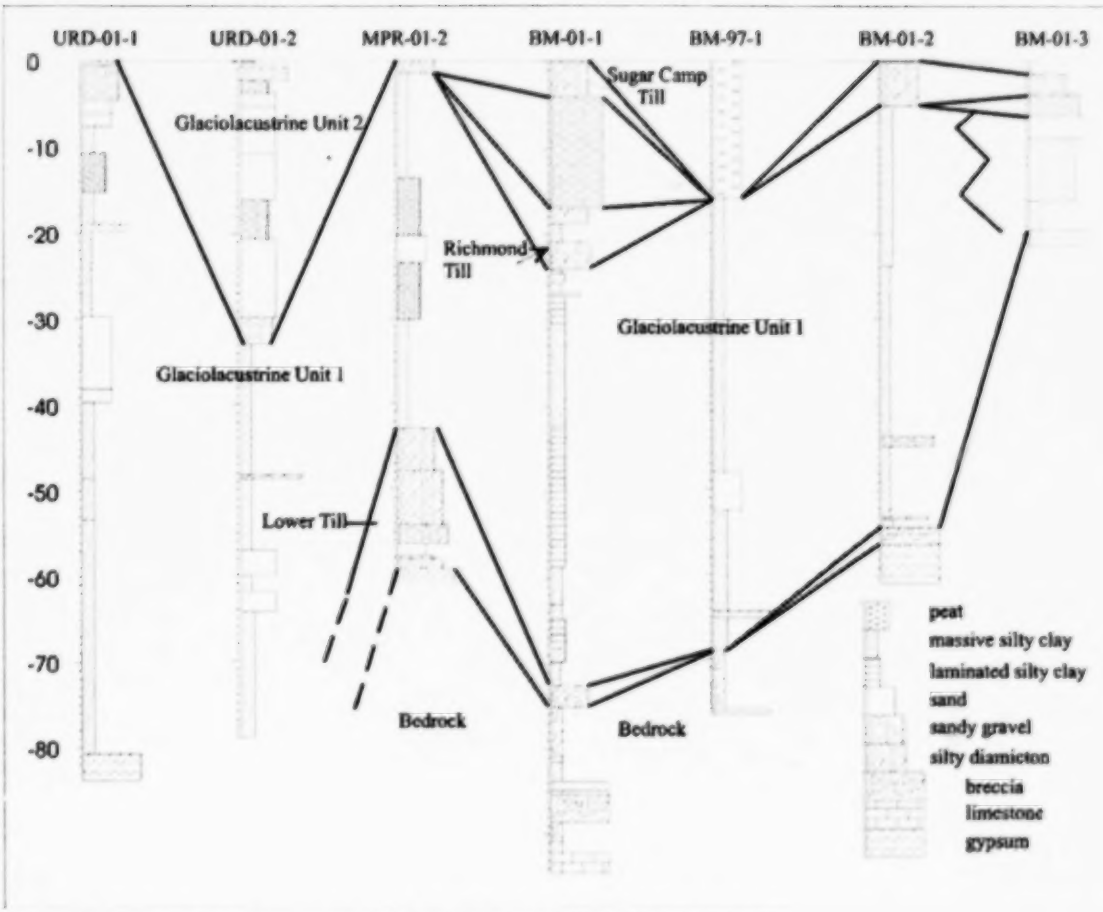

Figure 3. Stratigraphy and correlation of TGI drillholes within the Big Marsh lowlands.

A package of coarse gravel, sand, boulders and red-brown silty diamicton interpreted as a glacial till overlies Carboniferous bedrock and breccia in the deeper part of the Big Marsh lowlands to the north (MPR-01-1, and BM-01-1, and 2; Fig. 3). Thicknesses range from 0.3 m to 16.5 m, although the exact boundary of the lower till unit is sometimes difficult to establish. The till unit contains locally derived, angular clasts of white gypsum, black micritic limestone in a silty clay matrix, and also includes a high percentage of grey-green mafic, and white, pink and green granitic pebbles and cobbles.

Interglacial Peat and Wood

D. G. Kelley (1955) noted a thin organic seam sandwiched between two tills in the village of Whycocomagh (Fig. 2). Mott and Prest (1967) described the organic section as containing wood fragments, intercalated with grey organic silty clay. A date of >44,000 yr B P(GSC-290) was obtained from a piece of wood in the peat section. Another till-buried organic site was discovered near Ashfield (Figs. 2, 6) and is described below.

Glaciolacustrine Unit 1

Overlying the bedrock/breccia and the Lower Till in the River Denys Basin is a sequence consisting of red-brown and grey-brown clay, silty clay, and sand with minor gravel beds. This fine-grained unit ranges in thickness from 13 m to >40 m. Textures

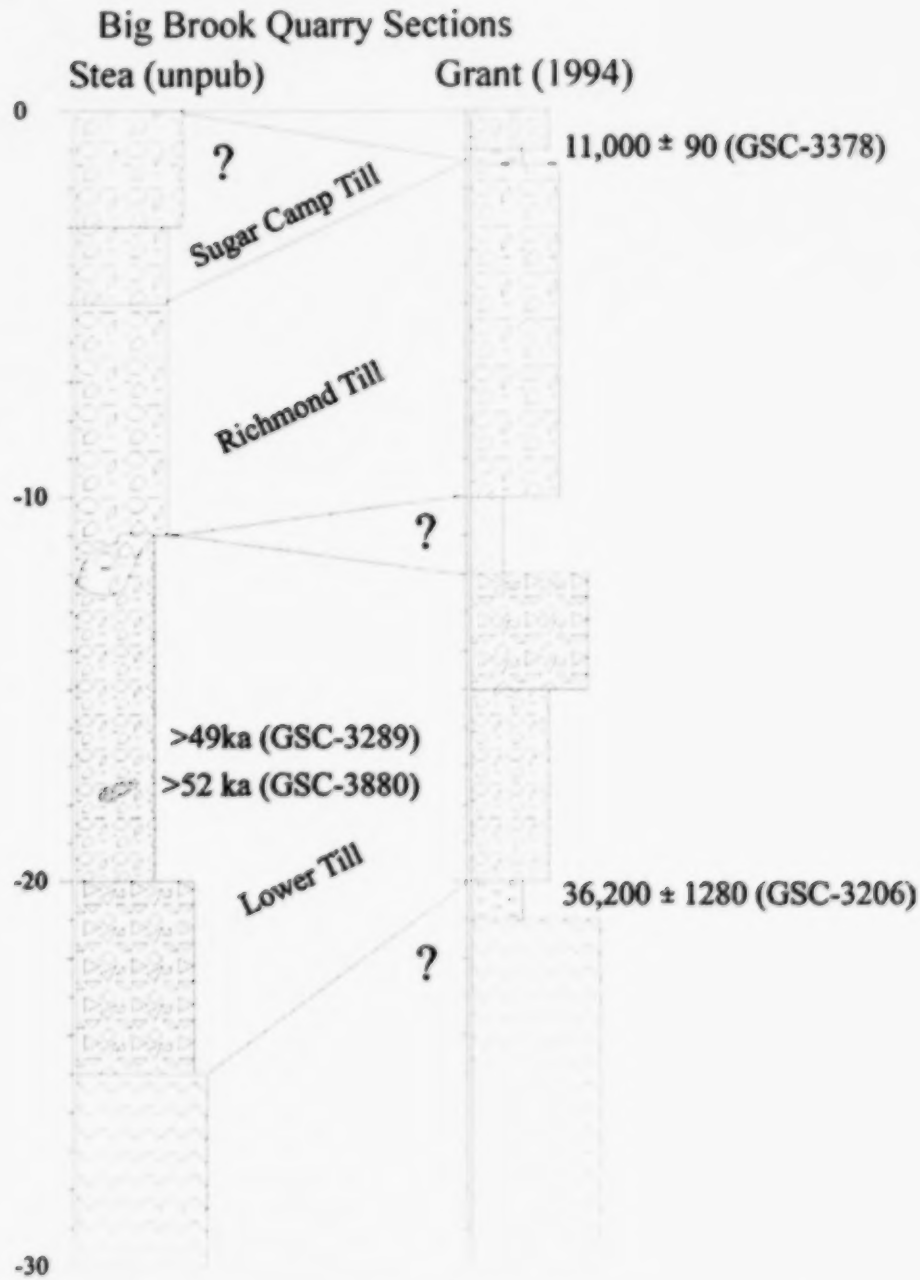

Figure 4. Stratigraphic sections and radiocarbon ages from the Cenozoic reference section at Big Brook (see facies legend, Fig. 3).

range from massive silty clay and clay to thinly laminated clay and silty clay, sometimes deformed by faulting or folding. Dropstones are rare throughout the unit, and occur as well rounded pebbles of various lithologies, but predominantly white quartz, grey and green siltstone, and sandstone. Sandy beds range from fine- to coarse-grained. Rhythmically bedded zones are present but rare. Magnetic susceptibility, natural gamma and conductivity geophysical logs (Fig. 5) demonstrate the inherent homogeneity of the unit by showing few excursions. The conductivity measurements in the order of 70-200 mS/m in unit 2 are indicative of glaciolacustrine sediments, based on a comparison of conductivity measurements with marine mud in the Champlain sea whose values are as high as 1200 mS/m (Hyde and Hunter, 1998). Conductivity is a good indicator of pore water salinity (Hyde and Hunter, 1998).

Richmond Till

A reference section for the Richmond Till (Grant and King, 1984) occurs at Big Brook Quarry. At this locality a calcareous, greyish-red, matrix-supported diamicton with allocthonous igneous and metamorphic pebbles overlies the oxidized Lower Till, with an erosional/tectonic contact including southward-oriented wedges of till (Fig. 4).

A road cut just south of the town of Ashfield, Inverness County (Fig. 2), revealed 2-3 m of reddish-brown silty diamicton overlying a quartz-pebble gravel, yellowish medium sand, and black and grey, organic silty clay (Figs. 6a, 7). The surface diamicton intrudes the lower quartz gravel in a series of clastic wedges, trending southward. Clast fabric in the surface diamicton is reasonably well oriented and exhibits a shallow, preferred plunge direction, indicating a lodgment till origin (Fig. 7; Dreimanis, 1989). The direction of ice flow indicated by the till fabric is east-southeastward, and is further verified by the ~10% content of diorite erratics, derived from large dioritic plutons in the Creignish Hills to the northwest (Keppie, 2000). The clast fabric has a substantial scatter, explicable by later reworking, possibly through several ice flow phases (Stea and Finck, 2001). The quartz-pebble gravel at the Ashfield section is similar to Cretaceous outliers elsewhere in Nova Scotia which are dominantly quartz arenites (Stea and Pullan, 2001). It is difficult to conceive of Quaternary gravel containing such a high percentage of quartz, considering the varied local source areas. However, the lower organic material was found to contain a pollen assemblage indicating a Quaternary interglacial/interstadial deposition with abundant tree pollen, especially spruce (R. J. Mott, personal communication, 2003). The upper till is therefore correlative with the Richmond Till, and the quartz gravel may have been incorporated from formerly extensive Mesozoic deposits (Stea and Pullan, 2001).

Above glaciolacustrine unit 1 in drillhole BM-01-1 is a grey-red silty diamicton, interpreted as the Richmond Till (Fig. 3). It contains a high percentage of allocthonous, dark grey-green mafic rocks, including basalt (~14%), pink, green and white granite (12%), and local green and maroon siltstone and sandstone (70%).

Tang (1970) described three till units in the Mullach Brook Valley north of Whycocomagh which were being evaluated as a source of placer gold. The lowest till unit contained sandstone and shale clasts derived from southward to eastward flow across regions underlain by Carboniferous bedrock to the north of the site, and is therefore correlated with the Richmond Till.

Sugar Camp Till (Big Brook Quarry)

At the Big Brook Quarry ("Stea section"; Fig. 4) the Richmond till is overlain by two brown till units, with high clast/matrix ratios, and a locally derived pebble lithology featuring limestone and shale clasts. The middle till is a correlative of the Sugar Camp Till, as defined in the Sugar Camp Quarry type section (see below).

At drillhole BM-01-1 (Fig. 3) in the River Denys Basin the surface unit in the region, a reddish-brown diamicton, occurs in many of the holes in this area, and is similar in texture and pebble assemblage to the underlying Richmond Till. Although it is most likely a reworked or hybrid till unit (cf. Stea and Finck, 2001) derived

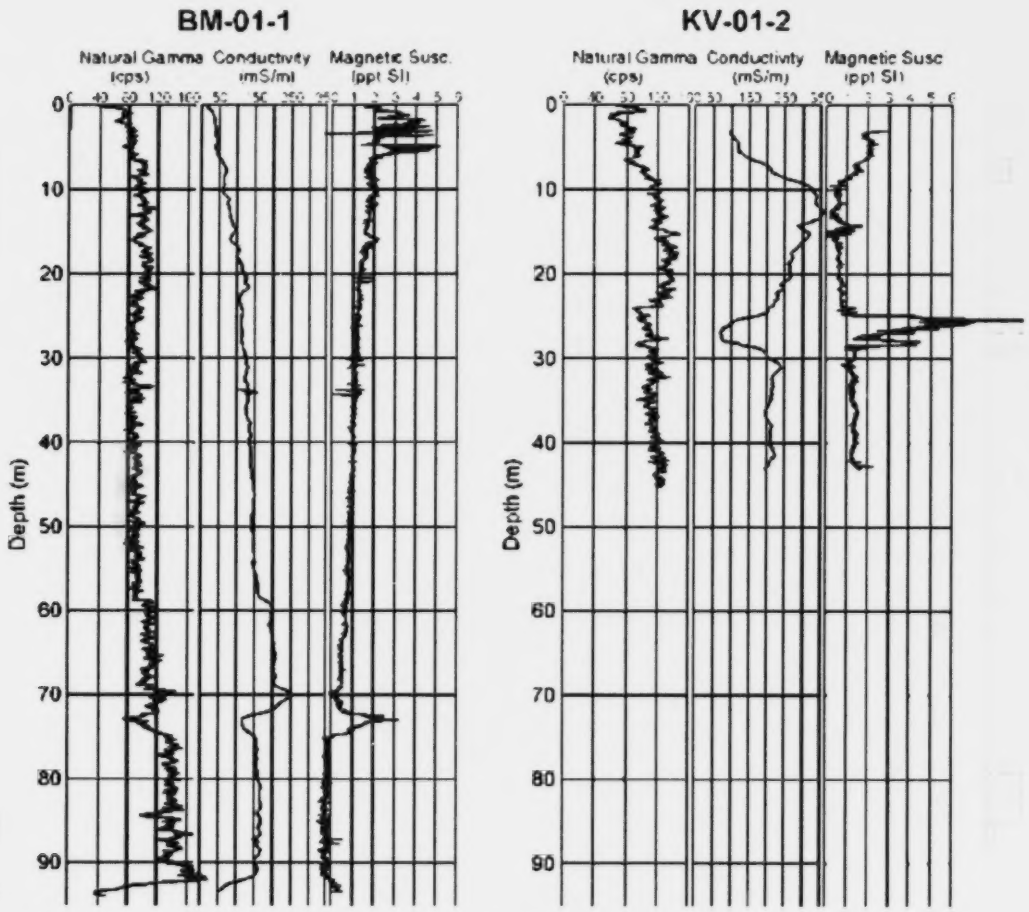

Figure 5. Geophysical logs from TGI diamond-drill holes in the River Denys Basin and River Inhabitants Lowlands.

from glacial mixing of the earlier Richmond Till during several ensuing glacial flow phases, it is also designated as the Sugar Camp Till. At BM-01-1 the Richmond Till correlative and the Sugar Camp Till units are separated by a thick gravel unit (Fig. 3). Total thickness of the two units ranges from a veneer along the western edge of the basin to 25 m at drillhhole BM-01-1.

Tang's (1970) middle till unit at Mullach Brook is composed of quartzite, diorite and granite clasts derived from highlands to the south and southwest, indicating a northward flow. Based on this evidence the middle till in Tang's sequence is considered a correlative of the Sugar Camp Till.

Late-glacial Interstadial Peat and Wood and Overlying Till?

A 10 cm thick thin peat layer was found at the top of Big Brook section overlain by diamicton and grey clay (Fig. 4; R. J. Mott, personal communication, 2002). The organic peat layer yielded an age of 11,000 yr BP (GSC-3778) and had a pollen spectrum dominated by sedges and ferns with some willow and birch (Mott *et al.*, 1986; Grant, 1994). One metre of grey stony clay and reddish-brown stony clay diamicton overlies the peat, interpreted as a glaciolacustrine deposit (Grant, 1994). A road cut near River Denys Centre

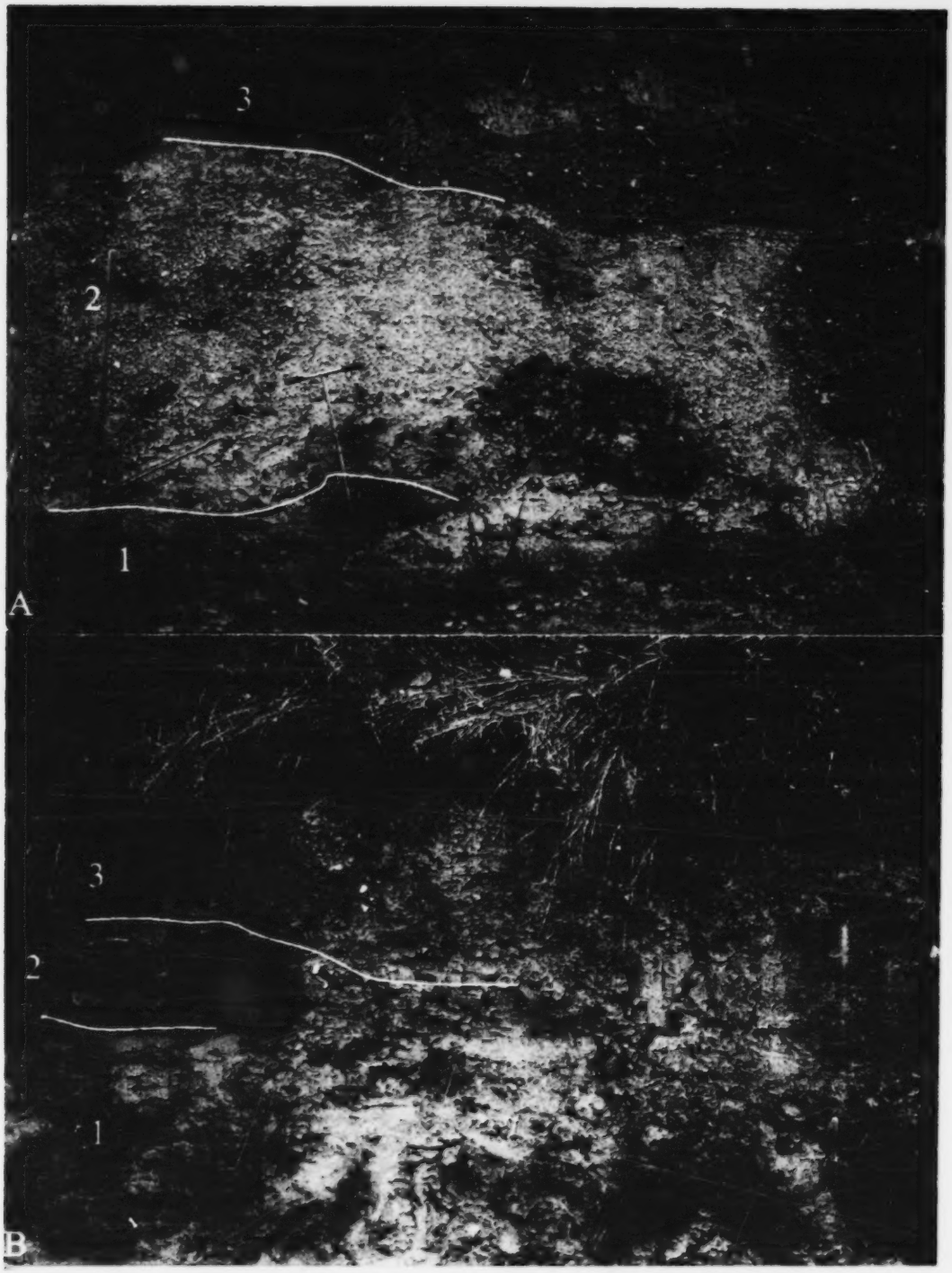

Figure 6. Photos from the (A) Ashfield section (Fig. 2); (1) lower interglacial organics, (2) quartz gravel, and (3) Richmond Till. (B) River Denys Centre; (1) till, (2) paleosol dated 11.4 ka, and (3) till?

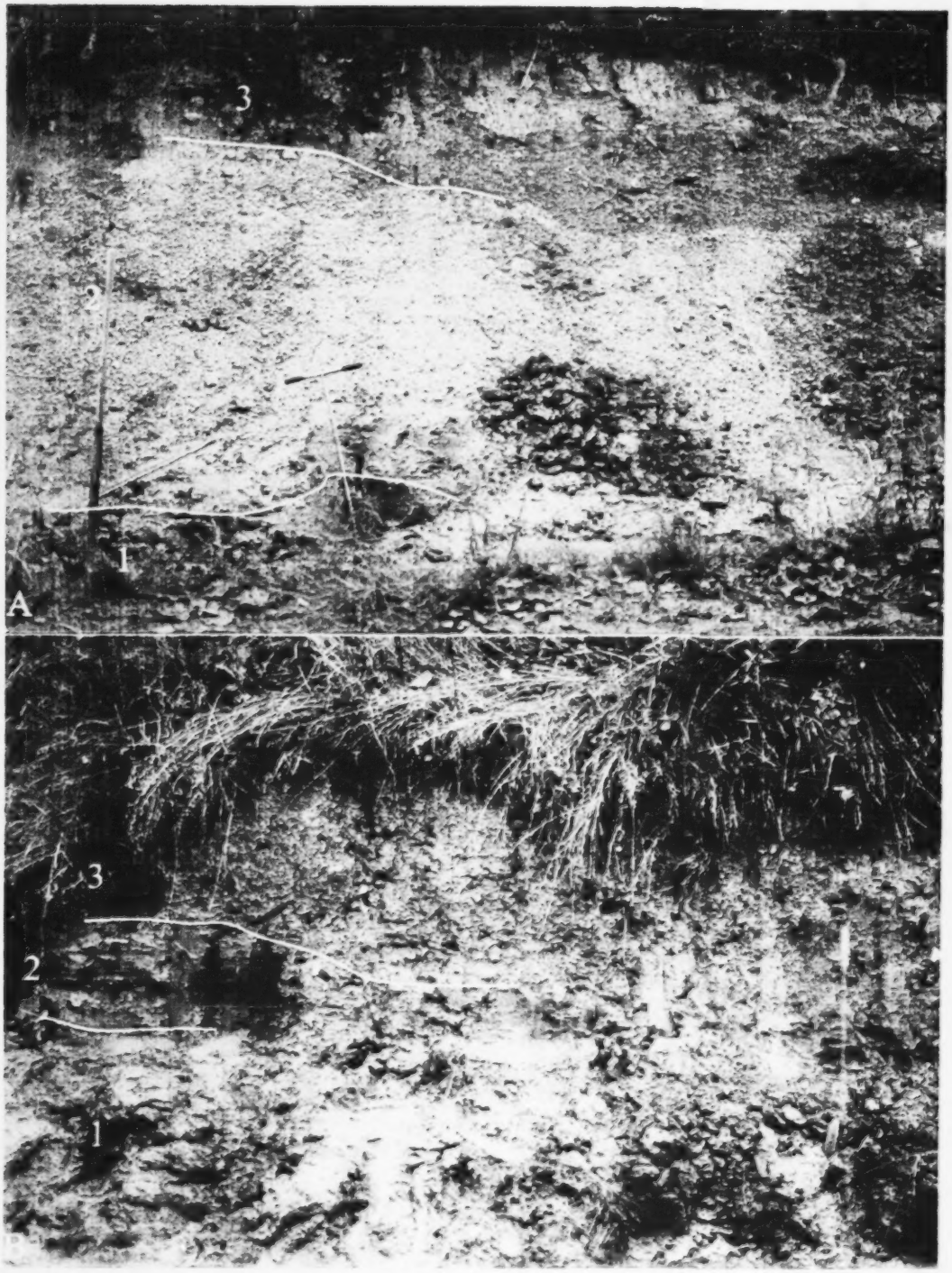

Figure 6. Photos from the (A) Ashfield section (Fig. 2): (1) lower interglacial organics, (2) quartz gravel, and (3) Richmond Till. (B) River Denys Centre: (1) till, (2) paleosol dated 11 4 ka, and (3) till?

Figure 7. Schematic diagram of the Ashfield section, (1) lower interglacial organics, (2) quartz gravel, (3) Richmond Till. Stereo plots show till fabric from the Richmond Till with inferred glacial flow directions.

(Fig. 6b) revealed 1 m of reddish brown, silty clay diamicton over a 5-10 cm thick peat layer, sandwiched between ~10 cm thick layers of grey silty clay. The organic paleosol was dated at 11,400 ± 100 yr B P (GSC-6520). Pollen from the organic bed shows late-glacial assemblages and, therefore, the zone is correlative with the late-glacial organic zone at Big Brook (R. J. Mott, personal communication, 2002). The diamicton over the peat layer thickens upslope along the road exposure, while the nearly horizontal peat layer dips below the drainage trench. More data are needed to establish the genesis of this intriguing deposit.

Lithostratigraphy of the River Inhabitants Lowlands

Based on seismic reflection testing (Pullan *et al.*, 2001) and previous indications of deep surficial cover, six drillholes were completed throughout the River Inhabitants Lowlands (Figs. 8, 9). A stratigraphic profile from north to south across the lowlands was constructed using drillholes KV-01-1, KV-01-2, DR-01-1, BR-01-1 and ML-01-1 (Fig. 9). Also within the lowland region is a previously described natural exposure of Quaternary sediments at River Inhabitants (Grant, 1994) and a new exposure at the Sugar Camp gypsum quarry. The Sugar Camp gypsum quarry (Fig. 10) is designated in this study as the type section for the Quaternary stratigraphic units of the lowland regions of southwest Cape Breton Island. The East Milford Quarry section (Mott and Grant, 1985; Stea *et al.*, 1992) is the equivalent stratigraphic section on mainland Nova Scotia.

Bedrock

Windsor Group evaporites, biogenic and clastic rocks underlie most of the River Inhabitants Lowlands and are overlain by thick Quaternary sediments. In the southern part of the lowlands near Sugar Camp, grey-white carbonate-rich gypsum with nearly horizontal bedding was intersected at a

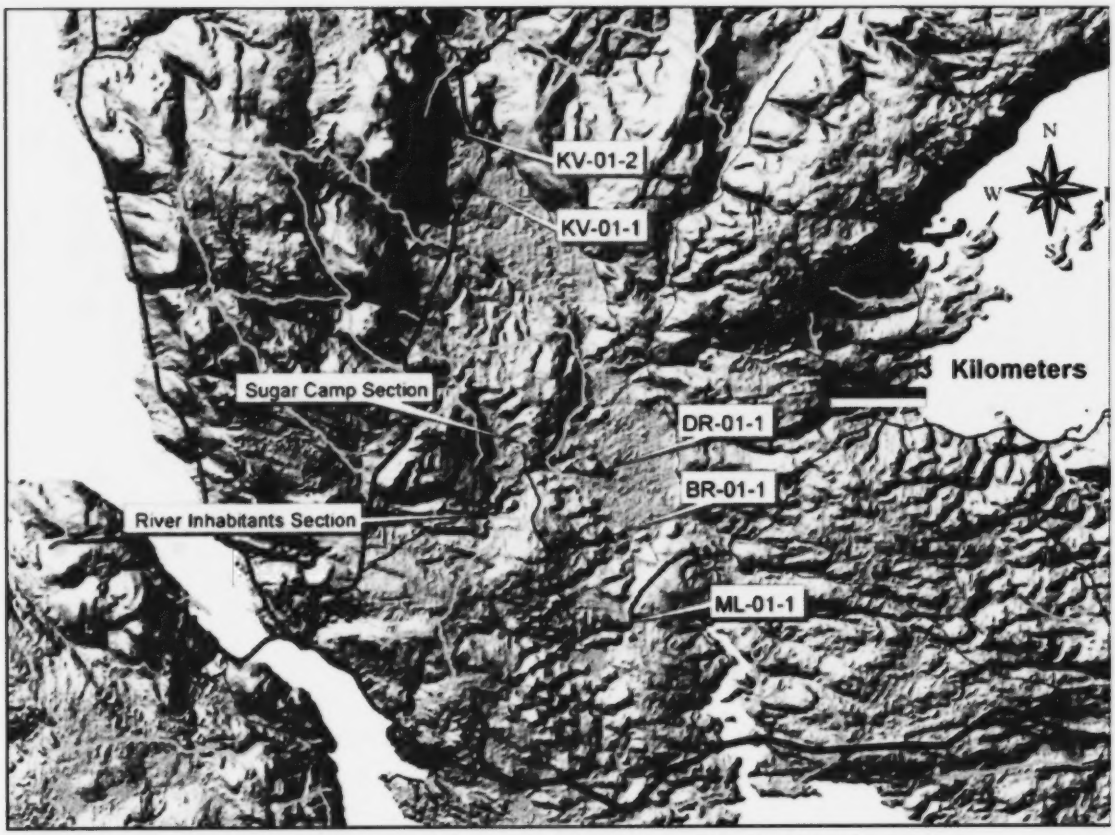

Figure 8. Location of reference sections and TGI diamond-drill holes in the River Inhabitants Lowlands.

depth of 14.2 m (ML-01-1) and at 53.6 m (BR-01-1) in the south (Fig. 9). At drillhole ML-01-1 near MacIntyre Lake, bedrock is an alternating green and maroon laminated mudstone with some mottling, characteristic of the Mabou Group (R. Boehner, personal communication, 2002).

None of the Kingsville area drillholes intersected bedrock (KV-01-1, 2; Fig. 9). The lowermost unit encountered was a light blue-grey silty clay and breccia containing pebbles of pink gypsum and satin spar veins near the base drillhole. In KV-01-1 this unit graded into a dark grey to black silty clay with abundant carbonate boulders. A sample from this unit was barren of palynomorphs (R. Fensome, personal communication, 2002). The maximum thickness of this unit is not known since two drillholes stopped short of intersecting bedrock.

Lower Till

A grey-brown to dark grey, matrix-supported silty diamicton is found directly on top of gypsum bedrock in most of the Sugar Camp sections (Fig. 10). Locally, layers of woody debris including large pieces of wood are found within the till unit and in boulder layers. At the Barbarton Road drillhole, resting on bedrock at a core depth of -46.8 m is a matrix-supported blue-grey till with gypsum and limestone clasts (Fig. 9). Overlying this till is a laminated clayey silt, and an organic silty diamicton.

Glaciolacustrine Unit 1

At Sugar Camp Quarry a brownish silty clay diamicton (Lower Till?) with few clasts overlies

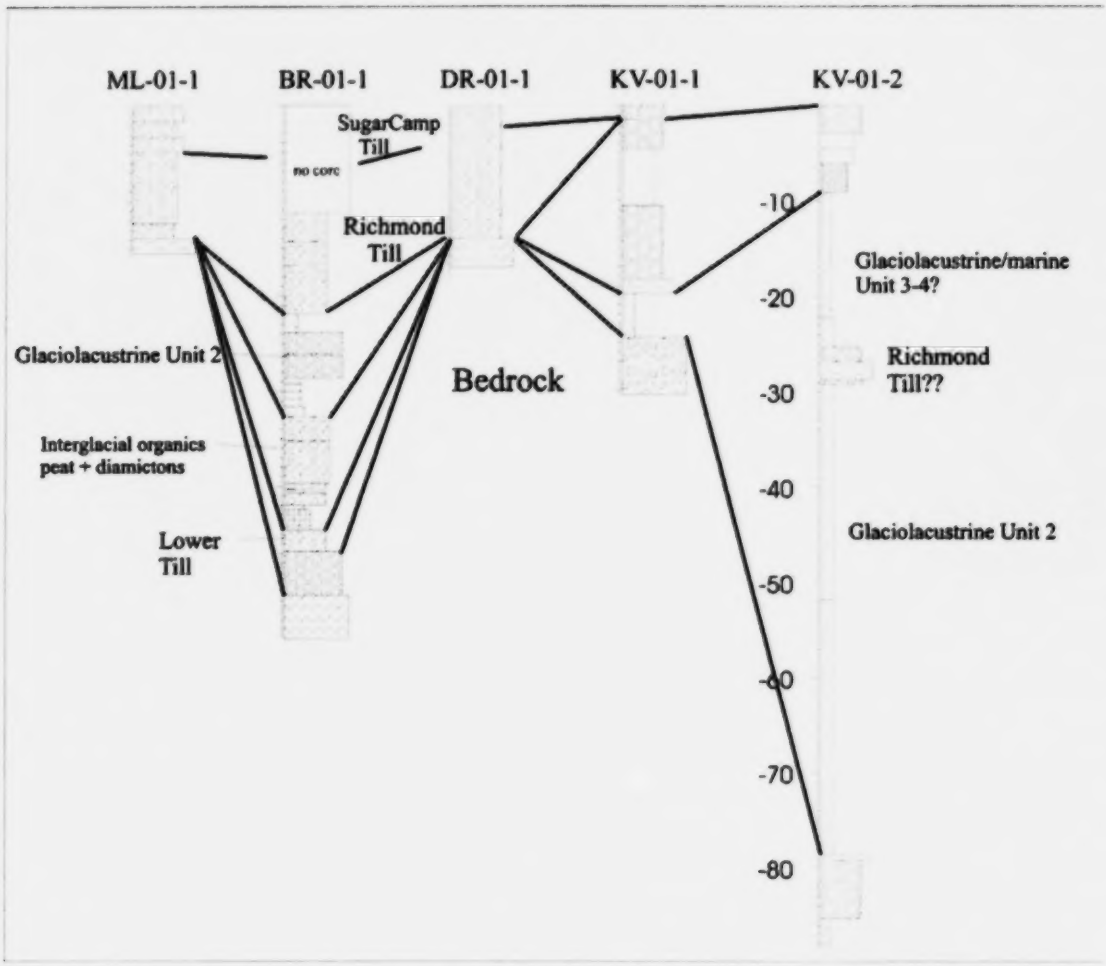

Figure 9. Stratigraphy and correlation of TGI drillholes within the River Inhabitants Lowlands (see facies legend, Fig. 3).

gypsum bedrock and develops gradually upsection into a rhythmically laminated silty clay and sand, with calcareous concretions (Fig. 10). This inorganic section is overlain by ~3 m of organic silty clay with layers of peat and woody debris. The interglacial organic horizon with wood fragments represents a marker horizon that can be used to stratigraphically separate similar glaciolacustrine facies.

Interglacial Peat (Paleosol)

The River Inhabitants section was first described in 1855 by J. W. Dawson and later by Mott and Grant (1985) and Grant (1994). The river is carved into Carboniferous bedrock, except for the vicinity of the section were it has intersected an erosional channel infilled with Quaternary sediment. At the base of the section is a 2-4 m thick package of peat and wood layered with organic silty clay, dipping to the west. The peat layers are deformed, with boudinaged peat lenses (Grant, 1994). The organic zone is overlain and intercalated near the top of the sequence with locally derived, shaly, gravelly sand. Radiocarbon dating of balsam fir in the organic zone yielded an age of >39,000 yr BP (GSC-1402).

At Sugar Camp Quarry an organic zone of variable thicknesses with peat, wood and organic

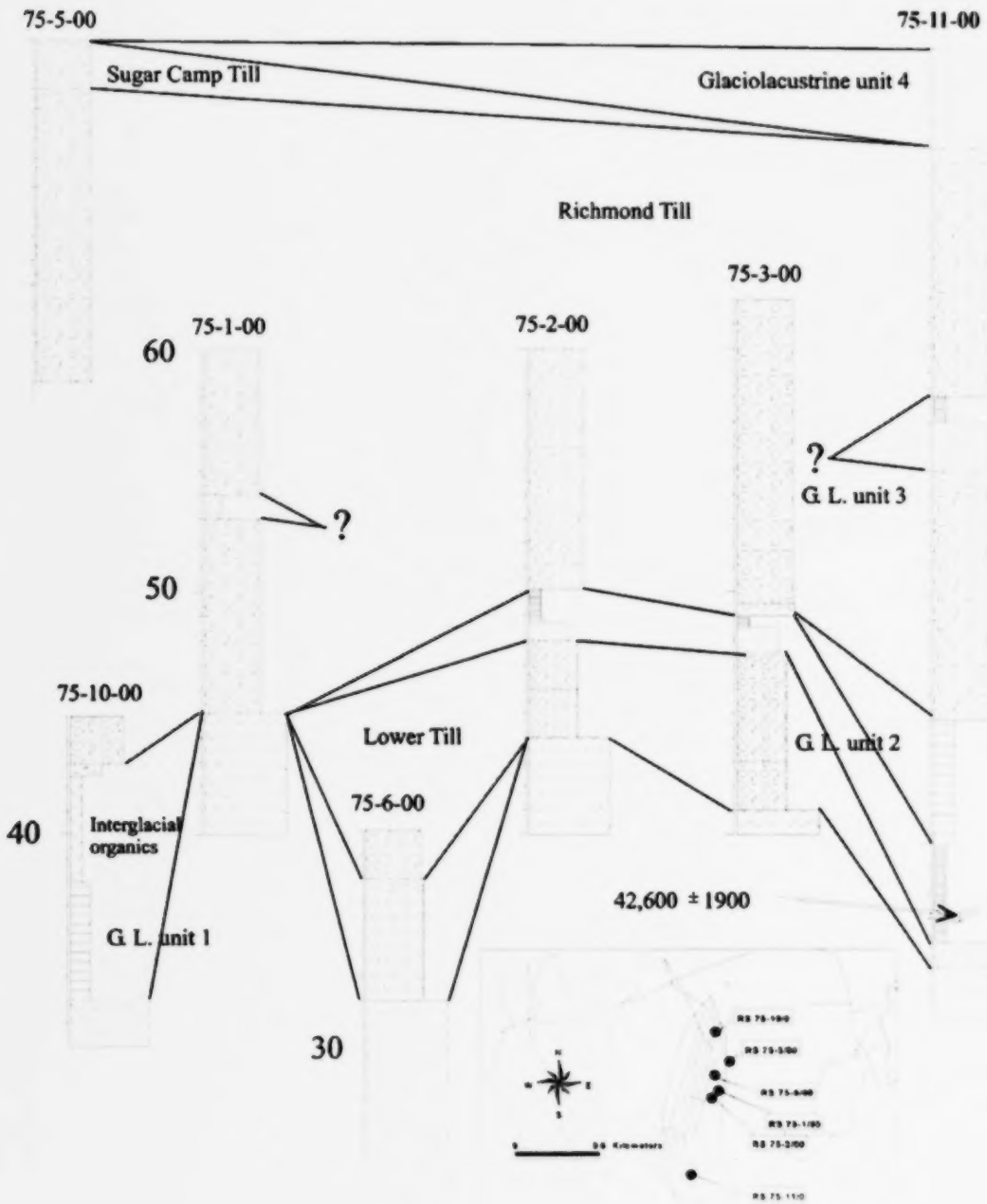

Figure 10. Stratigraphic sections from the Sugar Camp quarry (see facies legend, Fig. 3).

clay occurs near the base of the quarry section (e.g. 75-11-00; Fig. 10) both underlain and overlain by glaciolacustrine sediments (Figs. 10, 11). Large pieces of wood were recovered at several sites and identified as spruce *(Picea)* and fir *(Abies)* (R. J. Mott, personal communication, 2001). An accelerator mass spectrometry (AMS) radiocarbon date on one piece of wood produced a finite age of 42,600 ± 1900 yr B P (R. J. Mott, personal communication, 2001).

At the Barbarton Road drillhole section (BR-01–1; Fig. 9, 11) the lowest till unit is overlain by ~5 m of organic diamicton and silty clay, and a thin layer of peat and wood representing a non-glacial interval of unknown duration and paleoclimate. The similarity in stratigraphic sequences strongly suggests a correlation with the nonglacial units at the Sugar Camp and River Inhabitants sections.

Glaciolacustrine Unit 2

At Sugar Camp Quarry ~4-6 m of rhythmically bedded silty clay and sand overlie interglacial grey organic clay (gyttja?) with wood fragments (Figs. 10, 11). The contact is gradational and conformable with organic grey clay in the rhythmically bedded couplets of coarse and fine sediment, gradually replaced upsection by inorganic reddish-brown silty clay.

Lying above organic diamicton facies in drillhole BR-01-1 is a ~10 m thick package of waterlain sediments and diamictons, beginning with red-brown highly deformed clayey silt, which becomes finely laminated (varved) upsection (Figs. 9, 11).

Richmond Till

At the Sugar Camp quarry sections a massive grey-red, silty diamicton overlies the organic clay, rhythmites and oxidized sand and gravel with an erosional contact. A stripping wall section reveals a large wedge of Unit 2 intruding the lower organic-bearing diamicton (Unit 1). The massive, silty till has been called Richmond Till by Grant and King (1984), as it forms the core of many large drumlins in Richmond County. At the Sugar Camp quarry the pebble assemblage of the Richmond Till is dominated by grey, green and maroon siltstone, conglomerate, pink and white granite, diorite and gabbro and minor mafic and felsic volcanics. The most likely source area is the Creignish Hills to the west, which host NeoProterozoic granite, diorite and mafic volcanic rocks of the Devonian Fisset Brook Formation. The implied ice movement direction is east-southeastward.

At the Barbarton Road drillhole nearly 10 m of grey-red polymictic, matrix-supported diamicton overlies the organic layers (Figs. 9, 11). The unit is greyish-red and calcareous, with abundant granite, dioritic, and red and grey mudstone clasts, and is correlative with the Richmond Till.

Glaciolacustrine Unit 3-4(?)

The Kingsville region of the River Inhabitants floodplain is underlain by ~6 m of sand, then nearly 15 m of reddish-brown massive silty clay (KV-01-1; Fig. 9). The stratigraphic position of this unit is unclear, as it overlies a polymictic till correlative with the Richmond Till, but is not apparently overlain by glacial advance deposits. Stream erosion could have removed till from the upper part of the section, making the unit a pre-glaciation deposit, but it is more likely that the unit postdates the last glacial retreat. The conductivity log of KV-01-1 (Fig. 5) shows a peak in the unit greater than 300 mS/m, suggesting brackish formational water within the unit (Douma and Nixon, 1993; Hyde and Hunter, 1998) and may indicate marine influence. An explanation based on underlying salt and gypsum bedrock may not be valid as high pore water conductivity values are not evident lower in the core and in other study boreholes overlying evaporitic bedrock (Fig. 5).

Sugar Camp Till

At Sugar Camp Quarry a till overlying the Richmond Till (Fig. 10) is similar in texture and colour but can be differentiated from the Richmond Till by the abundance in robust marine shell fragments *(Mercenaria sp?)* and coal clasts. The source of coal is likely to be the upper Port Hood Formation, which outcrops around the south and eastern side of Inhabitants Bay. Shell fragments were described by Grant (1994) in tills along

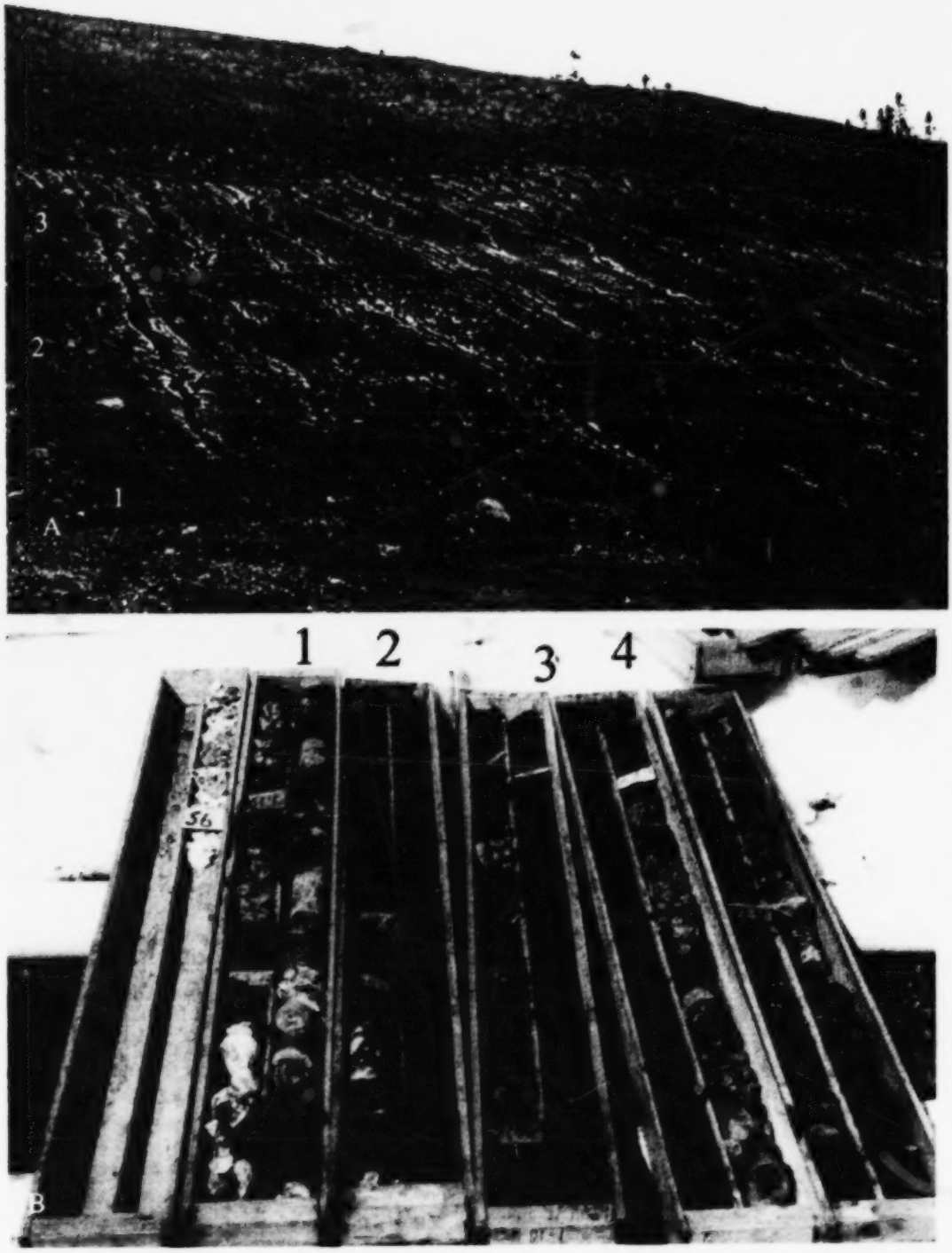

Figure 11. Photograph of the: (A) Sugar Camp section (1) lower till, (2) interglacial organic gyttja, (3) glaciolacustrine rhythmites (Unit 2), (4) Richmond Till. (B) Diamond-drill hole BR-01-1 (also see Fig. 9 for stratigraphy) (1) lower till, (2) interglacial peat, organic diamicton, (3) glaciolacustrine unit 2, (4) Richmond/Sugar Camp tills.

Janvrin Island as having been derived from onshore, northwestward ice flow. He also discovered that the shells are a temperate species, derived from interglacial deposits. These shell fragments must have been reworked from offshore marine areas as the Sugar Camp Till does not directly overlie interglacial beds in the study area.

Glaciolacustrine Unit 4

The uppermost stratigraphic unit at the Sugar Camp Quarry (Fig. 10) is a brown, silty clay (G. L. Unit 4), which is also a widespread surficial deposit throughout the River Inhabitants Lowlands. This fine-grained waterlain unit is interpreted as a glaciolacustrine unit, based on a lack of fossils and the lack of any other evidence of late marine submergence in the area, with the possible exception of a brackish environment in drillhole KV-01-1.

Interpretation

Mesozoic and Pre-Quaternary Events

The surficial strata that blanket the valleys and hills in Cape Breton range in age from Early Cretaceous (120 Ma) to recent. The oldest unconsolidated deposits are found in the narrow valley of Diogenes or Glen Brook near River Denys Centre (Fig. 2). These are the youngest pre-Quaternary sediments preserved in the region and should define the age of valley erosion (Goldthwait, 1924, p. 59), assuming that these unconsolidated sediments were deposited in the valleys that they are presently found in. Dickie (1986) noted the correlation of Cretaceous outliers and faults and proposed that the sediments were deposited and preserved in pre-existing fault-bounded valleys or in karst depressions. Using high resolution reflection seismic profiling, Stea and Pullan (2001) demonstrated significant folding and faulting of Early Cretaceous deposits along the Rutherford Road fault zone in the Musquodoboit Valley of mainland Nova Scotia. Faulting of the Diogenes Brook Cretaceous sediments, and other mainland outliers, had been previously noted (Guernsey, 1929; Akande and Zentilli, 1984; Stea and Fowler, 1981) but the significance had not been elaborated. Grant (1994, p. 25) also suggested that the Diogenes Brook outlier was infaulted on a major thrust fault system that forms the contact between the Creignish Hills and River Denys Basin (Lynch and Brisson, 1996). If the Cretaceous sediments were deposited before faulting then the age of the thrust fault can be inferred as post-Early Cretaceous. The relatively young age (Mesozoic-Cenozoic) of basin margin tectonics was used by Stea and Pullan (2001) to develop the argument that most of the present topography is a Mesozoic structural remnant and not due to differential erosion, either by Tertiary fluvial incision and/or glacial erosion (cf. Goldthwait, 1924; Mathews, 1975; Grant, 1994). Recent discoveries of fault-bounded Cretaceous outliers in Antigonish (Stea *et al.*, 1986) and Sussex, New Brunswick (R. Fensome, personal communication, 2003), attest to the regional nature of this tectonic event.

Another important observation is the elevation of the Diogenes Brook outlier, between 100 and 130 m above present sea level. The preservation of this elevated Cretaceous outlier for ~100 million years suggests a substantial cover of post-Early Cretaceous sediment and it is significant that the highest outlier is also apparently the oldest (Dickie, 1986). The inference drawn from this observation is that much more cover had been stripped from this region than at other localities. The lack of a marine or terrestrial Late Cretaceous and Tertiary sedimentary record also implies regional uplift and erosion throughout these time periods, and is further evidence of exhumation of a substantial volume of Mesozoic sediment (Stea and Pullan, 2001). Evidence from thermal maturation studies of lignites (Hacquebard, 1984; Stea *et al.*, 1996) suggests a cover of between 600 m and 1 km, as does forward modelling of apatite fission track data (Arne *et al.*, 1989) assuming a geothermal gradient of 30°C/km. An estimate of cover thickness can be obtained by using an empirically derived Appalachian denudation rate (10 m/Ma; Stanford *et al.*, 2002) and multiplying by the length of erosional time (~100 million years). By this admittedly crude method we estimate a 1 km cover thickness of Early Cretaceous strata.

In summary, the development of uplands and lowlands in Cape Breton was largely a result of

Mesozoic-Cenozoic tectonism and subsequent unroofing of a thick blanket of Mesozoic sediments. Thrust tectonics evident in the Bay of Fundy (Withjack, 1998) and central Nova Scotia (Stea and Pullan, 2001) may be due to plate interactions in Cretaceous-early Tertiary times, when a regional extensional stress regime changed to an ENE-WSW-directed compressional stress field (Faure and Angelier, 1996). Regional uplift and erosion throughout the Tertiary can be explained by lithospheric flexure or forebulge migration due to subsiding offshore basins (King, 1972; Keen and Beaumont, 1990). This flexure model also explains later subsidence (e.g. Grant, 1994) that resulted in the lowering of terrestrial Early Cretaceous outliers in mainland Nova Scotia to well below present sea level (Stea and Pullan, 2001).

Quaternary Events

During the Quaternary ice sheets advanced and retreated over Cape Breton Island during ~16 major glacial periods over ~2 million years. The record of glaciations however, span only the last 200,000 years of the Quaternary after most of the existing Cretaceous cover was removed, and the exhumed fault valleys began to be excavated by glaciers. The presence of a thick, sandy sediment cover of Mesozoic age may have helped to prevent glacier movement and deposition in the region by shunting basal water away from the incipient ice sheets.

Illinoian? Lower Till

The age of the lower till has not been established directly, but assuming a last interglacial age for the overlying peat/paleosol, it would likely relate to the Illinoian glaciation or Marine Oxygen Isotope Stage 6 (~230 ka). At the Big Brook reference section, wood contained within the lower till could have either been inherited from older interglacial deposits (Yarmouthian?) or more likely tectonically emplaced or overprinted (e.g. Stea and Finck, 2001) into the lower till by glacial tectonics, which are clearly evident at the site.

Glacier Lake Grant

After the Illinoian glacial advance that deposited the lower till, the ice sheet probably receded out of the isostatically depressed Bras d'Or Lakes, leaving a series of interconnected basins either open to the ocean or depending on the rate and mode of retreat, glacial lake basins (cf. Grant, 1994). In the Sugar Camp Quarry, rhythmites interpreted as glacio-lacustrine overlie the lower till and are conformably overlain by organic peat of the last interglacial. They therefore represent the formation of a glacial lake in the River Denys Basin at the end of the Illinoian glaciation. The name Glacial Lake Grant is used to denote this water body, which would have been the oldest precursor of the Bras d'Or Lakes. It is named after Douglas Grant who did much to establish the paleogeography and chronology of ice marginal lakes in Cape Breton.

Sangamon Interglaciation (MIS 5) Peat/paleosol and the Middle Wisconsinan Problem

New specimens of organic material, including peat, organic clay and wood relating to the last interglacial period, were obtained from a drillhole (BR-01-1), the Sugar Camp gypsum quarry reference section and the Ashfield road section. These localities are added to the impressive number of sites in Cape Breton that feature non-glacial sediments of the warm period that pre-dates the Wisconsinan glaciation (Grant, 1994). The reference locality of these interglacial deposits in Cape Breton is at East Bay, where three layers of organics beds interrupted by fluvial gravel deposits record a progressively cooling climate from temperate to boreal/tundra (Mott and Grant, 1986; deVernal *et al.*, 1986; Grant, 1994). Wood from these sites generally produces ages with Carbon 14 activity that is not discernable from background radiation, but there are a growing number of Middle Wisconsinan ages including a finite date in this study of ~42 ka at Sugar Camp Quarry. The validity of these Middle Wisconsinan ages has been challenged based on the potential for contamination by minute quantities of young carbon from rootlets (Mott and Grant, 1986). U/Th disequilibrium dating of wood and peat from these beds has produced ages ranging from ~130 ka to 47 ka (de Vernal *et al.*, 1986), with most of the dates spanning Marine Oxygen Isotope Stage 5 (MIS 5; 128-74 ka). The youngest ages in the sequence were derived from beds where uranium migration

is a distinct possibility, hence producing anomalously young ages (Stea *et al.*, 1992). The importance of the youngest ages is that they negate the concept of a significant MIS 4 ice advance in eastern Canada (e.g. Grant and King, 1984), and imply ice free conditions lasting throughout MIS 5, 4 and 3. A possible solution to this problem lies in the application of optically stimulated luminescence dating to interglacial organic gyttja and conformably overlying glaciolacustrine deposits at Sugar Camp. This alternative dating method can be used as a check on the anomalous Mid-Wisconsinan radiocarbon age obtained from the organics.

Glacial Lake Cameron

At Sugar Camp Quarry, rhythmites overlie Sangamon (MIS 5) organic beds. The rhythmites formed in a glacial lake that developed both in the River Denys and in the River Inhabitants Lowlands. A similar concept was proposed by Grant (1994, p. 116) who termed the lake "Glacial Lake Cameron". Grant's evidence for the glacial lake in the Bras d'Or lowlands was primarily in coastal sections along East Bay that feature interbedded marine and lacustrine organic clays. Stea *et al.* (2002) interpreted these as interglacial marine deposits. Drillhole BM-01-1 in the River Denys lowlands, however, shows the development of 50-60 m thick deposits of glaciolacustrine clay and silt (GL Unit 1; Fig. 3) after deposition of the lower till. The development of a long-lived glacial lake in the River Denys lowlands, rimmed on three sides by highlands, would require an ice dam in the Bras d'Or Lakes, as was suggested by Grant (1994). The lack of dropstones implies that the ice dam was some distance away, and not in direct contact with the lake, a possibility if glacier expansion was first restricted to the Cape Breton Highlands (Fig. 12).

The concomitant development of a glacial lake predating till deposits in the River Inhabitants lowland, as seen at the Sugar Camp section (Fig. 12), would have to be explained by an ice dam in the lowlands to the south. This lake may not have been synchronous with the lake in the River Denys lowlands in the north, but drainage routes for the southern Glacial Lake Cameron would have presumably been through the northern and southern gaps of the Maple Brook Syncline (Fig. 12).

Caledonia Phase

The first major glacial advance during the Wisconsinan glaciation was toward the east-southeast, depositing a thick silty till termed the Richmond Till (Grant and King, 1984). The provenance and fabric of Richmond Till in the River Denys and River Inhabitants lowlands implies an eastward flow (090°-120°; CP 1; Fig. 12) as does the orientation of drumlinized terrain in that area (Stea *et al.*, 2003). Later ice flow changed to a more southeastward orientation (140°-160°; CP 2; Fig. 12). A correlative silty till forms the core of many drumlins in southeast Cape Breton Island (McClenaghan and DiLabio, 1996; Grant, 1994). Stea *et al.* (1998) designated the early flow as the Caledonia Phase, deriving the term from Rampton *et al.* (1984), who proposed that a major southeast-ward ice flow (140°-160°) crossed the Caledonia Highlands of New Brunswick. Grant (1994) termed these early flow phases Phases B and C in Cape Breton Island. The provenance data from this study suggest that the early eastward flow (Caledonia Phase 1) was more extensive and consistent than in Grant's (1994) reconstruction, which features a lobe of ice in the south that swings to the northwest in the study area.

Stea *et al.* (1992), Grant (1994) and Stea *et al.* (1998) hypothesized that the Caledonia Phase was initiated by ice growth in the northern Appalachians, perhaps the White Mountains area, an idea first suggested by Chalmers (1895). The extent and duration of the eastward flow event is in doubt, but it appears to have affected much of northern Nova Scotia and southeast New Brunswick (e.g. Rampton *et al.*, 1984; Stea and Finck, 1984) and there is some evidence that it may have affected west-central New Brunswick (Seaman, 2000). It may also be correlative with early eastward flow in northern New Brunswick (Parkhill and Doiron, 2003), which would certainly rule out a Laurentide source. It would seem likely that if the Cape Breton Highlands were a site of glacierization, as postulated by Grant (1994), then the higher northern Appalachians would also have nucleated a large ice sheet.

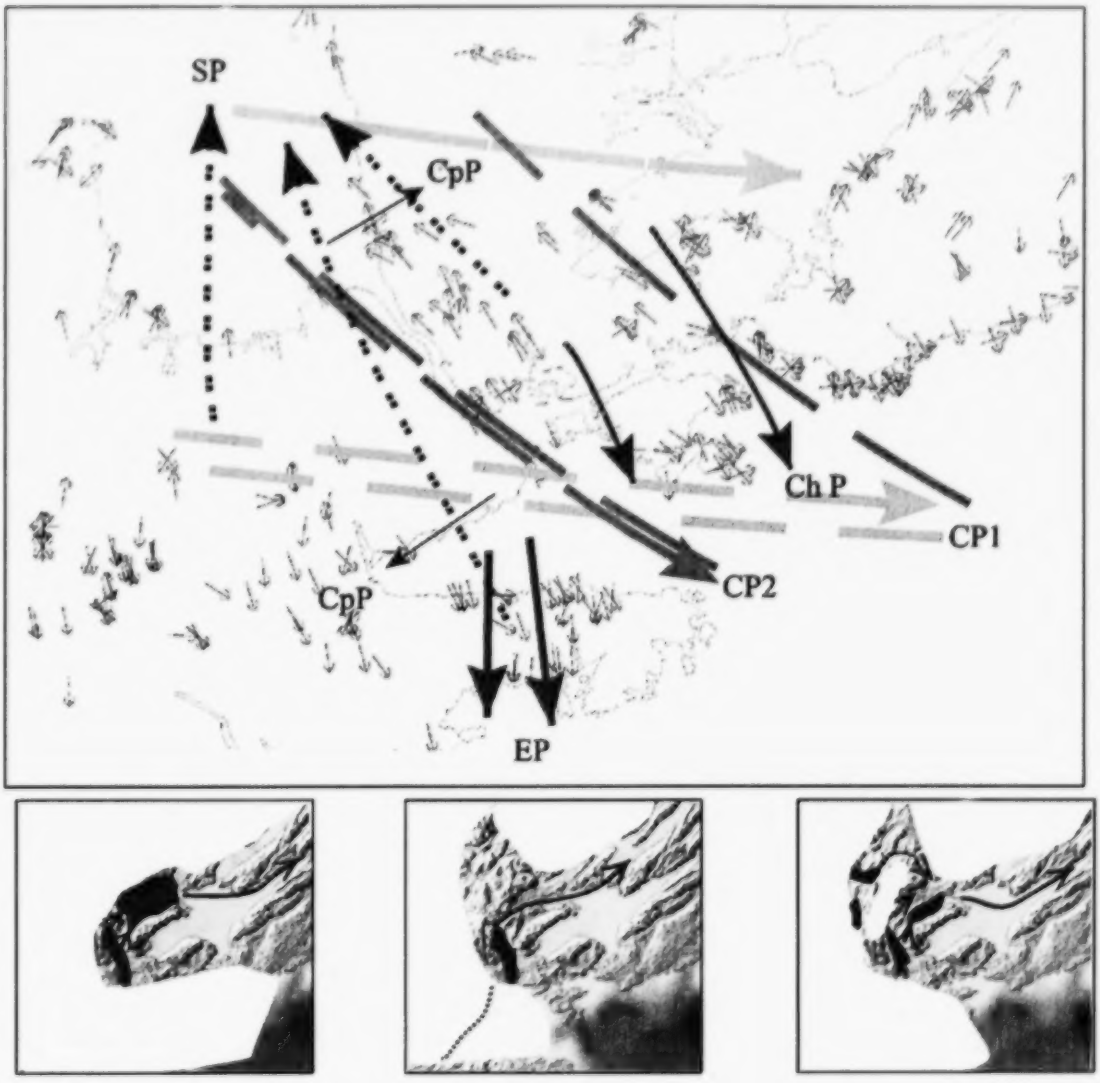

Figure 12. (A) Summary of ice flow phases and the development of glacial lakes in the study area. CP1, 2-Caledonia Phase; EP-Escuminac Phase; SP-Scotian Phase; ChP-Chignecto Phase; CpP-Collins Pond Phase. (B) (A) Glacial Lake Grant, Glacial Lake Cameron (1); (B) Glacial Lake Cameron (2). Dotted line represents an ice retreat margin when the lake basin becomes brackish. (C) Glacial Lake Dawson (1). Arrows are meltwater routes.

A later shift to the southeast is well documented by striae and till provenance on mainland Nova Scotia (e.g. Stea *et al.*, 1986; Stea and Finck, 2001), and in Cape Breton (Grant, 1994; Phase C2). McClenaghan and DiLabio (1995, 1996) interpreted the southeast flow phase to be derived from a local ice centre (Escuminac Ice Centre) over the Magdalen Shelf rather than the Laurentide Ice Sheet. A key point is the lack of Laurentide erratics in northern Nova Scotia (Stea *et al.*, 1998) and along the west coast of Cape Breton (Grant, 1994, p. 119). It is hypothesized that the

local Appalachian ice caps "held off" the Laurentide ice sheet or directed it into the Laurentian Channel (Prest and Grant, 1969; Grant, 1994).

The age of this event is uncertain, but from the Sugar Camp Quarry section it is apparent that glacial lake development immediately post-dated the last interglacial, and was followed by emplacement of the Richmond Till. Deposits of the last interglacial have been dated by U/Th disequilibrium methods between ~130 and 80 ka (de Vernal *et al.*, 1986), if we discount the anomalous Mid-Wisconsinan ages. This would establish an Early Wisconsinan (MIS 4 ~75-64 ka) age for the till-forming event. A younger, bracketing age may be provided by the Bay St. Lawrence section in northern Cape Breton Island where a marine sand bed dated between 21 ka and 50 ka separates two till-like diamictons (Stea *et al.*, 1992; Grant, 1994; Stea *et al.*, 1998).

Glacial Lake Cameron (2)

At drillhole KV-01-2 a thick sequence of silty clay overlies a till that can be correlated with the Richmond Till (Fig. 9). Evidence of brackish/ marine porewater from the conductivity logs suggests that the clay may have been deposited in a lake/estuary with some connection to the ocean. During the Middle Wisconsinan an ice sheet of considerable thickness was in retreat and at Bay St. Lawrence in northern Cape Breton, a marine shell-bearing sand between tills may represent that period of glaciomarine deposition on a submerged, recently deglaciated landscape. Also, there is no evidence of Late Wisconsinan submergence in the region. It is suggested that the silty clay unit in KV-O1-2 may have been deposited in a transitional glacial lake/glaciomarine estuary environment as ice retreat opened up an outlet to the Atlantic Ocean (Fig. 12). This conclusion is tentative and would have to be verified by age dating.

Scotian Phase

The River Inhabitants and Sugar Camp Quarry sections exhibit two till units that can be related to regional ice flow events, mapped by striae and landform trends. The uppermost Sugar Camp Till unit at the sections provides evidence of a switch to southern provenance with the introduction of coal clasts derived from the Port Hood Formation outcropping around Inhabitants Bay. This flow direction also produced the Creignish Hills Till on the highlands of southwestern Cape Breton Island, associated with ribbed moraine, northwestward-trending striae and meltwater channels (Stea and Feetham, 2003) In southeast Cape Breton, McClenaghan and Dilabio (1995, 1996) clearly demonstrated that a till sheet was formed during this northward ice flow phase.

Northwestward flow across the study area can be traced across 300 m highlands and represents a major glacier flow phase that was directed into the Cape Breton Channel, possibly to merge with Laurentide ice in the Laurentian Channel (Stea *et al.*, 1998). Stea *et al.*, (1998) correlated these flow directions in southern Cape Breton (Grant, 1994; Phase D) with till-forming glacier flow on mainland Nova Scotia, also directed into the Cape Breton Channel through Georges Bay. They termed the event the Scotian Phase.

Stea (1995) and Stea *et al.* (1998) petrologically linked the till in mainland Nova Scotia formed during the Scotian Phase to the Scotian Shelf End Moraine complex which was dated between 15 and 18 ka (~18-21 ka (calibrated age); King, 1996). The extent and elevation of Scotian Phase erosional and depositional landforms is consistent with thick local ice (>1 km) over much of the region.

Till stratigraphy and provenance in mainland Nova Scotia indicate clearly that the main Late Wisconsinan flow that predated the Scotian Phase and extended out to the shelf edge was due to ice flow radiating from a centre in the Magdalen Shelf termed the Escuminac Ice Centre (Stea *et al.*, 1998). It is uncertain whether Escuminac flow was southeastward along a similar path to earlier flows across the island (McClenaghan and DiLabio, 1996), or whether Cape Breton Island was under an ice divide during the Escuminac Phase for part or all of the Late Wisconsinan and only produced southward flow recorded in northern mainland Nova Scotia (Stea *et al.*, 1998). Evidence of southward ice flow on the mainland of Nova Scotia

suggests that latter possibility. Vigorous ice flow during the Scotian Phase may have overprinted much of the previously deposited Escuminac Phase till (e.g. Stea and Finck, 2001).

Chignecto Phase

Grant (1994) mapped a series of spatially separate glacier flow patterns (Phases E-F-G) that post-date the Scotian Phase. Similarly, Stea and Finck, (1984) mapped a southwestward ice flow phase (Ice Flow Phase 4) that postdates the Scotian Phase, and produced till and eskers in mainland Nova Scotia. Stea *et al.* (1998) termed the event the Chignecto Phase. At several localities southeastward striae (Grant, 1994; Phase E) postdate the strong northwestward flow (Scotian Phase). The youngest till sheet at Mullach Brook (Tang, 1970) and at Big Brook quarry (Fig. 4) may relate to one or more of these late flow phases, but lack of provenance data precludes any conclusions at this time.

The most likely scenario for these discordant flow patterns is a re-organization of ice to local centres and possible re-advances during this phase. The Chignecto Phase southwest flow pattern has been traced to a morainal belt off the eastern shore of mainland Nova Scotia, which was dated between 12.7 ka and 14 ka (~15-16.7 CAL; Stea *et al.*, 1996). Josenhans and Lehman (1999) presented evidence for a significant re-advance in the Cabot Strait ca. 13.2 ka (~15.8 CAL) which (Stea, 2001) linked to local glaciers by pebble lithology.

Glacial Lake Dawson (1)

Surface glaciolacustrine clay deposits in the River Inhabitants and River Denys lowlands relate to the retreat of Chignecto Phase glaciers from the Bras d'Or Lowlands. Grant (1994) envisioned remnant ice in the Bras d'Or Lakes and in southern Cape Breton, to explain ice-dammed lakes in these lowlands. The age of these lakes in western Cape Breton is just before 11.8 ka, based on radiocarbon dates of a paleosol overlying silty clay deposited in the lake (Stea and Mott, 1998). Radiocarbon dating of Chase Pond south of the Bras d'Or Lakes suggests an even earlier deglaciation (~13 ka), making a late remnant ice cap in the lakes a remote possibility (Stea and Mott, 1998). Another possibility is that ice remaining over Kelly Mountain, the Boisdale Hills and St. Andrews Channel forced meltwater through a higher outlet at East Bay (Fig. 12C). The elevation of this lake is uncertain, although there are glaciofluvial delta deposits near River Denys at ~30 m elevation (Stea and Feetham, 2003).

Collins Pond Phase

Near River Denys Centre a diamicton, possibly till, overlies a peat-paleosol dated to 11.4 ka (~13.4 CAL), suggesting a late re-advance of ice. This event is better represented in western Cape Breton where a glacial lake reformed as ice re-advanced and blocked the Gulf of St. Lawrence meltwater outlets (Stea and Mott, 1998). It is thought that much of the Cape Breton Highlands and the southern Gulf of St. Lawrence harboured a glacier during the Younger Dryas Chronozone (Stea and Mott, 1998).

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References

Akande, S. O. and Zentilli, M. 1984: Geologic, fluid inclusion, and stable isotope studies of the Gays River lead-zinc deposit, Nova Scotia, Canada; Economic Geology, v. 79, p. 1187-1211.

Arne, D. C., Duddy, I. R. and Sangster, D. F. 1989: Thermochronologic constraints on ore formation at the Gays River deposit, Nova Scotia, Canada, from apatite fission track analysis; Canadian Journal of Earth Sciences, v. 27, p. 1013-1022.

Chalmers, R. 1895: Report on the surface geology of eastern New Brunswick, northwestern Nova Scotia and a portion of Prince Edward Island; Geological Survey of Canada, Annual Report 1894, v. 1, no. 7, pt. m, 144 p.

deVernal, A., Causse, C., Hillaire-Marcel, C., Mott, R. J. and Occhietti, S.1986: Palynostratigraphy and Th/U ages of upper Pleistocene interglacial and interstadial deposits on Cape Breton Island, Eastern Canada; Geology, v. 14, p. 554-557.

Dickie, G. B. 1986: Cretaceous deposits of Nova Scotia; Nova Scotia Department of Mines and Energy, Paper 86-1, 54 p.

Douma, M. and Nixon F. M. 1993: Geophysical characterization of glacial and postglacial sediments in a continuously cored borehole near Ottawa, Ontario; *in* Current Research, Part E; Geological Survey of Canada, Paper 93-1E, p. 275-279.

Douma, M., Hunter, J. A. and Good, R. L. 1999: Borehole geophysical logging; Chapter 4 *in* A Handbook of Geophysical Techniques for Geomorphic and Environmental Research, R. Gilbert (compiler); Geological Survey of Canada, Open File #3731, p. 57-67.

Dreimanis, A. 1989: Genetic classification of tills; *in* Genetic Classification of Glacigenic Deposits, eds. R. P. Goldthwait and Matsch, C. l. p. 17-84, Balkema, Rotterdam.

Evenson, E. B. 1971: The relationship of macro- and microfabric of till and the genesis of glacial landforms in Jefferson County, Wisconsin; *in* Till a symposium, ed R. P. Goldthwait, p. 345-364, Ohio State University Press.

Faure, S. T. A. and Angelier, J. 1996: State of intraplate stress and tectonism of northeastern America since Cretaceous times, with particular emphasis on the New England-Quebec igneous province; Tectonophysics, v. 255, 1-2, p. 111-134.

Finck, P. W., Stea, R. R. and Pullan, S. 1995: New discoveries of Cretaceous sediments near Shubenacadie, Nova Scotia; *in* Minerals and Energy Branch Report of Activities 1994, eds. D. R. MacDonald and K. A. Mills; Nova Scotia Department of Natural Resources, Report 95-1, p. 139.

Gillis, M. X. 1998: A report on the 1997-1998 exploration program for kaolin clays in the Musquodoboit, Stewiacke and Shubenacadie regions of Nova Scotia; Nova Scotia Department of Natural Resources, Assessment Report 98-041.

Goldthwait, J. W. 1924: Physiography of Nova Scotia; Geological Survey of Canada, Memoir 140; p. 60-103.

Grant, D. R. and King, L. H. 1984: A stratigraphic framework for the Quaternary history of the Atlantic Provinces; *in* Quaternary Stratigraphy of Canada - A Canadian Contribution to IGCP Project 24, ed. R. J. Fulton; Geological Survey of Canada, Paper 84-10, p. 173-191.

Grant, D. R. 1994: Quaternary Geology, Cape Breton Island, Geological Survey of Canada, Bulletin 482, 159 p.

Guernsey, T. D. 1927: Quartz sand and clay deposits, Melford, Cape Breton, Canada; Department of Mines, Geological Survey, Summary Report 1926, Part C, p. 110-124.

Hacquebard, P. A. 1984: Composition, rank and depth of burial of two Nova Scotia lignite deposits; *in* Current Research, Part A, Geological Survey of Canada, Paper 84-1a. p. 11-15.

Hunter, J. A., Pullan, S. E., Burns, R. A., Good R. L., Harris J. B. Pugin, A., Skvortsov, A. and Goriainov, N. N. 1998: Downhole seismic logging for high resolution reflection surveying in unconsolidated overburden; Geophysics, v. 63, p. 1371-1384.

Hyde, C. S. B. and Hunter, J. A. 1988: Formational electrical conductivity-porewater salinity relationships in Quaternary sediments from two Canadian sites; *in* Proceedings, SAGEEP'98, Symposium on the Application of Geophysics to Environmental and Engineering Applications, March 22-26, 1998, Chicago, IL, p. 499-510.

Josenhans, H. and Lehman, S. 1999: Late glacial stratigraphy and history of the Gulf of St. Lawrence, Canada; Canadian Journal of Earth Sciences, v. 36, p. 1327-1345.

Keen, C. E. and Beaumont, C. 1990: Geodymanics of rifted continental margins; Chapter 9 *in* Geology

of the Continental Margin of Eastern Canada, eds. M. J. Keen and G. L. Williams; Geological Survey of Canada, Geology of Canada, no. 2, p. 31-85.

Kelley, D. G. 1967: Baddeck and Whycocomagh map areas with emphasis on the Mississippian stratigraphy of central Cape Breton Island, Nova Scotia (11 K/2 and 11 F/14); Geological Survey of Canada, Memoir 351, 65 p.

Keppie, J. D. 2000: Geological map of the province of Nova Scotia; Nova Scotia Department of Natural Resources, Map ME 2000-1, scale 1:500 000.

King, L. H. 1972: Relation of plate tectonics to the geomorphic evolution of the Canadian Atlantic Provinces; Geological Society of America Bulletin, v. 83, p. 3083-3090.

King, L. H. 1996: Late Wisconsinan ice retreat from the Scotian Shelf; Geological Society of America Bulletin, v. 108, p. 1056-1067.

Lynch, G. and Brisson, H. 1996: Bedrock Geology Whycocomagh (11F14); Geological Survey of Canada, Open File 2917.

Mathews, W. H. 1975: Cenozoic erosion and erosion surfaces in eastern North America; American Journal of Science, v. 275, p. 818-824.

McClenaghan, M. B. and DiLabio, R. N. W. 1995: Till geochemistry and its implications for mineral exploration: southeastern Cape Breton Island, Nova Scotia, Canada; Quaternary International, v. 20, p. 107-122.

McClenaghan, M. B. and DiLabio, R. N. W. 1996: Ice flow history and glacial dispersal patterns, southeastern Cape Breton Island, Nova Scotia: implications for mineral exploration; Canadian Journal of Earth Sciences, v. 33, p. 351-362.

Mörner, N. A. 1973: A new find of till wedges in Nova Scotia, Canada; Geologiska Foereningen i Stockholm Foerhandlingar, v. 95, p. 272-273.

Mott, R. J., Grant, D. R. G., Stea, R. R. and Occhietti, S. 1986: Late-glacial climatic oscillation in Atlantic Canada equivalent to the Allerrd-Younger Dryas event; Nature, v. 323, no. 6085, p. 247-250.

Mott, R. J. and Grant, D. R. G. 1985: Pre-Late Wisconsinan paleoenvironments in Atlantic Canada; Géographie physique at Quaternaire, v. 39, p. 239-254.

Mott, R. J. and Prest, V. K. 1967: Stratigraphy and palynology of buried organic deposits from Cape Breton Island, Nova Scotia; Canadian Journal of Earth Sciences, v. 4, p. 709-724.

Parkhill, M. A. and Doiron, A. 2003: Quaternary geology of the Bathurst Mining Camp and implications for base metal exploration using drift prospecting; *in* Massive Suphide Deposits of the Bathurst Mining Camp, New Brunswick and Northern Maine, eds. W. D. Goodfellow, S. R. McCutcheon and J. M. Peter; Economic Geology Monograph, v. 11.

Prest, V. K. and Grant, D. R. 1969: Retreat of the last ice sheet from the Maritime Provinces - Gulf of St. Lawrence region; Geological Survey of Canada, Paper 69-33, 15 p.

Pullan, S., Hunter, J. A. M., Burns, R., Douma, M. and Stea, R. R. 2001: Testing of shallow seismic reflection technique, Cape Breton Island [NTS 11F10, 11F11 and 11F14]; in Minerals and Energy Branch Report of Activities 2000, Nova Scotia Department of Natural Resources; Report ME 2001-1, p. 73-81.

Rampton, V. N., Gauthier, R. C. Thibault, J. and Seaman, A. A. 1984: Quaternary geology of New Brunswick; Geological Survey of Canada, Memoir 416, 77 p.

Seaman, A. A. 2000. Glacial dispersal in west-central New Brunswick; Atlantic Geology, v. 36, p. 71-72.

Stanford-Scott, D., Ashley, G. M., Russell, E.,W-B., Brenner G. J. 2002: Rates and patterns of late Cenozoic denudation in the northernmost Atlantic Coastal Plain and Piedmont; Geological Society of America Bulletin. v. 114; no. 11, p. 1422-1437.

Stea, R. R. 1995: Late Quaternary glaciations and

sea-level change along the Atlantic Coast of Nova Scotia; unpublished Ph.D Dissertation; Dalhousie University, Halifax, 407 p.

Stea, R. R. 2001: Late-glacial stratigraphy and history of the Gulf of St. Lawrence: Discussion; Canadian Journal of Earth Sciences, v. 38, p. 479-482.

Stea, R. R., Boyd, R., Costello, O., Fader, G. B. J. and Scott, D. B. 1996: Deglaciation of the inner Scotian Shelf, Nova Scotia: correlation of terrestrial and marine glacial events; *in* Late Quaternary Palaeoceanography of the North Atlantic Margins, eds. J. T. Andrews, H. H. Bergsten and A. E. Jennings; Geological Society Special Publication, No. 111, p. 77-101.

Stea, R. R. and Feetham, M. 2003: Surficial geology map of the Whycocomagh Area (11 F/14); Nova Scotia Department of Natural Resources, Map ME 2003-1, scale 1:50 000.

Stea, R. R. and Finck, P. W. 1984: Patterns of glacier movement in Cumberland, Colchester, Hants, and Pictou Counties, northern Nova Scotia; *in* Current Research, Part A; Geological Survey of Canada, Paper 84-1A, p. 477-484.

Stea, R. R. and Finck, P. W. 2001: An evolutionary model of glacial dispersal and till genesis in Maritime Canada; *in* Drift Exploration in Glaciated Terrain, eds. B. McClenaghan, M. B. Bobrowski, P. T. Hall and S. J. Cook; Geological Society of London, Special Publications 185, p. 237-265.

Stea, R. R., Finck, P. W., Prime, G. and DeMont, G. J. 1995: New discoveries of silica sand and kaolinite near Brierly Brook, Antigonish County; *in* Minerals and Energy Branch Report of Activities 1994; Nova Scotia Department of Natural Resources, Report ME 1995-1, p. 159-162.

Stea, R. R., Finck, P. W., Pullan, S. E. and Corey, M. C. 1996: Cretaceous deposits of kaolin clay and silica sand in the Shubenacadie and Musquodoboit Valleys, Nova Scotia, Canada; Nova Scotia Department of Natural Resources, Mines and Minerals Branch, Open File Report ME 1996-3.

Stea, R. R. and Fowler, J. H. 1981: Petrology of Lower Cretaceous silica sands at Brazil Lake, Hants County, Nova Scotia; *in* Mineral Resources Division Report of Activities; Nova Scotia Department of Mines and Energy, Report 81-1.

Stea R. R. and Mott, R. J. 1998: Deglaciation of Nova Scotia, stratigraphy and chronology of lake sediment cores and buried organic sections;. Géographie physique et Quaternaire, v. 41, p. 279-290.

Stea, R. R., Mott, R. J., Belknap, D. F. and Radtke, U. 1992: The Pre-Late Wisconsinan Chronology of Nova Scotia, Canada; *in* The Last Interglaciation/Glaciation Transition in North America, eds. P. U. Clark and P. D. Lea; Geological Society of America, Special Paper 270, p. 185-206.

Stea, R. R., Piper, D. J. W., Fader, G. B. J. and Boyd, R. 1998: Wisconsinan glacial and sea-level history of Maritime Canada, a correlation of land and sea events; Geological Society of America Bulletin 110, no. 7, p. 821-845.

Stea, R. R. and Pullan, S. E. 2001: Hidden Cretaceous Basins in Nova Scotia; Canadian Journal of Earth Sciences, v. 38, p. 1335-1354.

Stea, R. R., Scott, D. B., Godfrey-Smith, D. and Mott, R. J. 2002: Sangamonian interglacial sea-levels of + 20 m in Maritime Canada; Geological Association of Canada and Mineralogical Association of Canada Joint Annual Meeting, May 27-29, 2002. Saskatoon, Saskatchewan.

Tang, P. S. 1970: Late Quaternary stratigraphy of Mullach Brook and adjacent areas, Cape Breton, Nova Scotia; M.Sc. thesis, Acadia University, Wolfville, Nova Scotia, Thesis 363, 88 p.

Preliminary Bedrock Geology of the Area Between Chebogue Point, Yarmouth County, and Cape Sable Island, Shelburne County, Southwestern Nova Scotia

C. E. White

Introduction

Detailed bedrock mapping in the southwestern Meguma Terrane of Nova Scotia, from Digby to Shelburne (Fig. 1), is part of a multi-year program initiated in 1998 by the Nova Scotia Department of Natural Resources. The principal goals of the project are to produce a series of 1:50 000-scale geological maps of the area, describe and interpret the sedimentary, igneous, metamorphic, and deformational history, and evaluate the economic potential. Reported here are results from field mapping completed during the summer of 2002, including a preliminary bedrock geology map of the area between Chebogue Point, Yarmouth County, and Cape Sable Island, Shelburne County. Mapping covered parts of NTS map areas 20O/08, 20O/09, 20P/05 and 20P/12 (Fig. 1). Details of the mapping program, previous geological investigations, and methodology were summarized by White *et al.* (1999), and preliminary results of the first four years (covering parts of NTS map areas 21A/12, 21A/05, 21B/08, 21B01, 21O/16, 20P/13) were presented by White *et al.* (1999, 2001), White and King (2002) and Horne *et al.* (2000).

Field Relations and Map Units

Introduction

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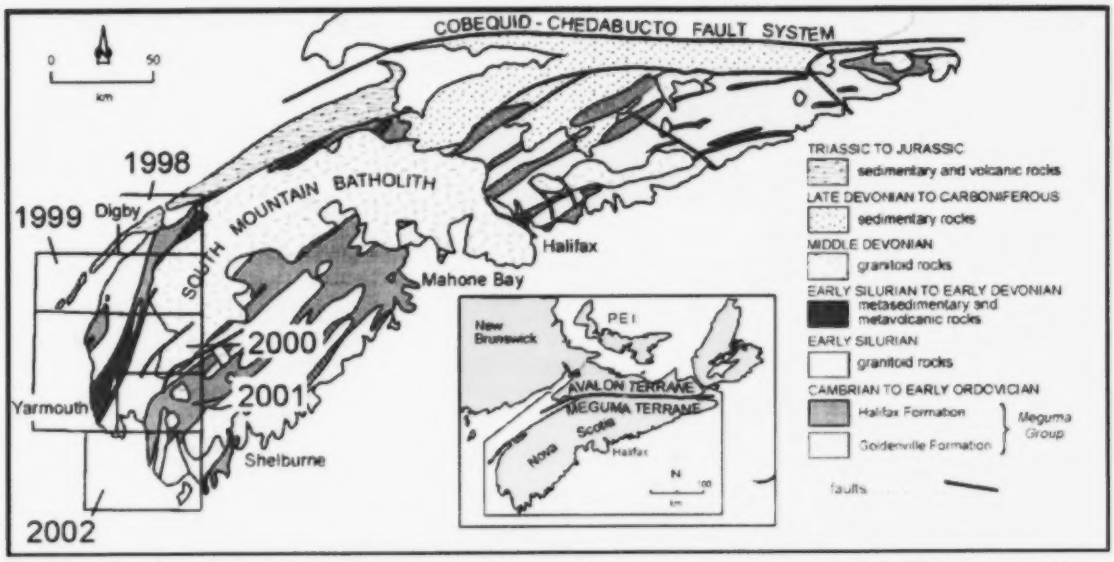

Figure 1. Simplified geological map of the Meguma Terrane, Nova Scotia, showing locations of mapped areas related to the Southwest Nova Scotia Mapping Project.

White, C. E. 2003: *in* Mineral Resources Branch, Report of Activities 2002; Nova Scotia Department of Natural Resources, Report 2003-1, p. 127-145

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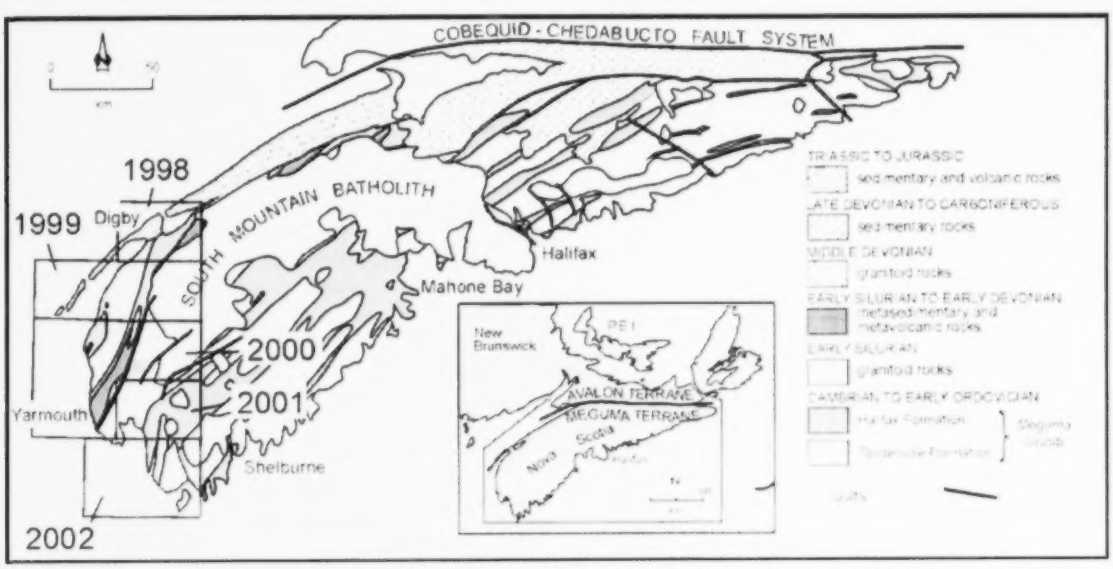

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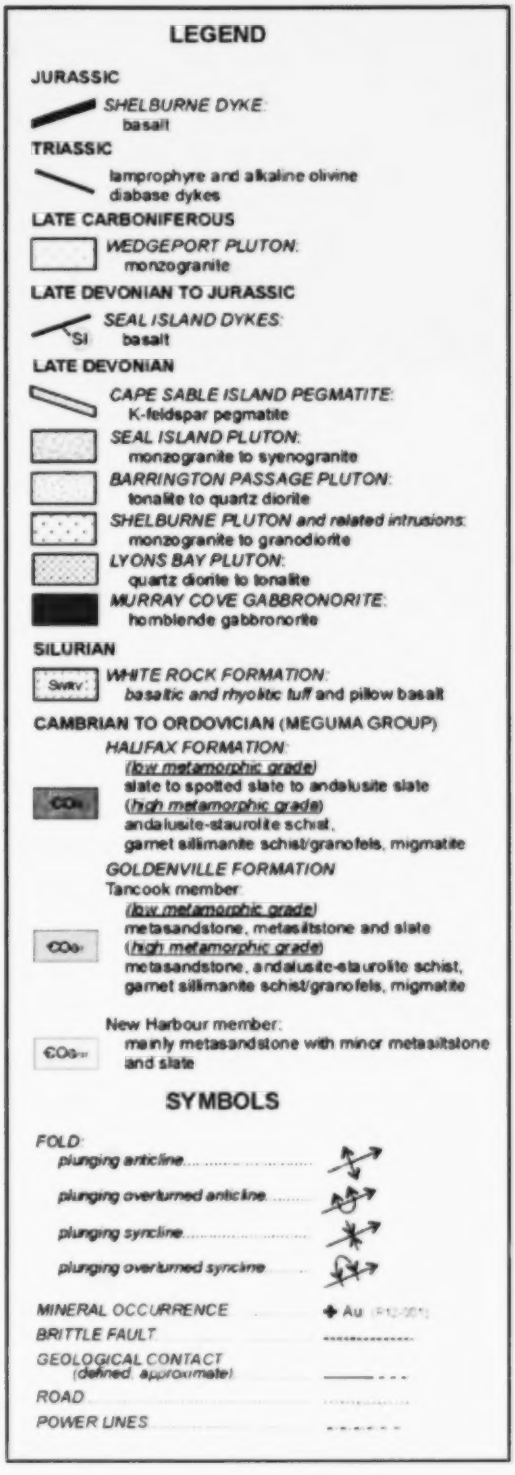
Cape Sable Island map area. They include the Cambrian to Ordovician Meguma Group, consisting of the Goldenville Formation and overlying Halifax Formation, and the Silurian White Rock Formation. These units have been deformed and regionally metamorphosed, with grade ranging from chlorite (greenschist facies) in the western half of the map area to sillimanite (amphibolite facies) in the eastern half. The metamorphic units are intruded by the Devonian Barrington Passage and Shelburne plutons, and the Carboniferous Wedgeport Pluton. The metamorphic units and Wedgeport Pluton are intruded by rare Early Mesozoic mafic dykes and sills (e.g. Pe-Piper and Reynolds, 2000).

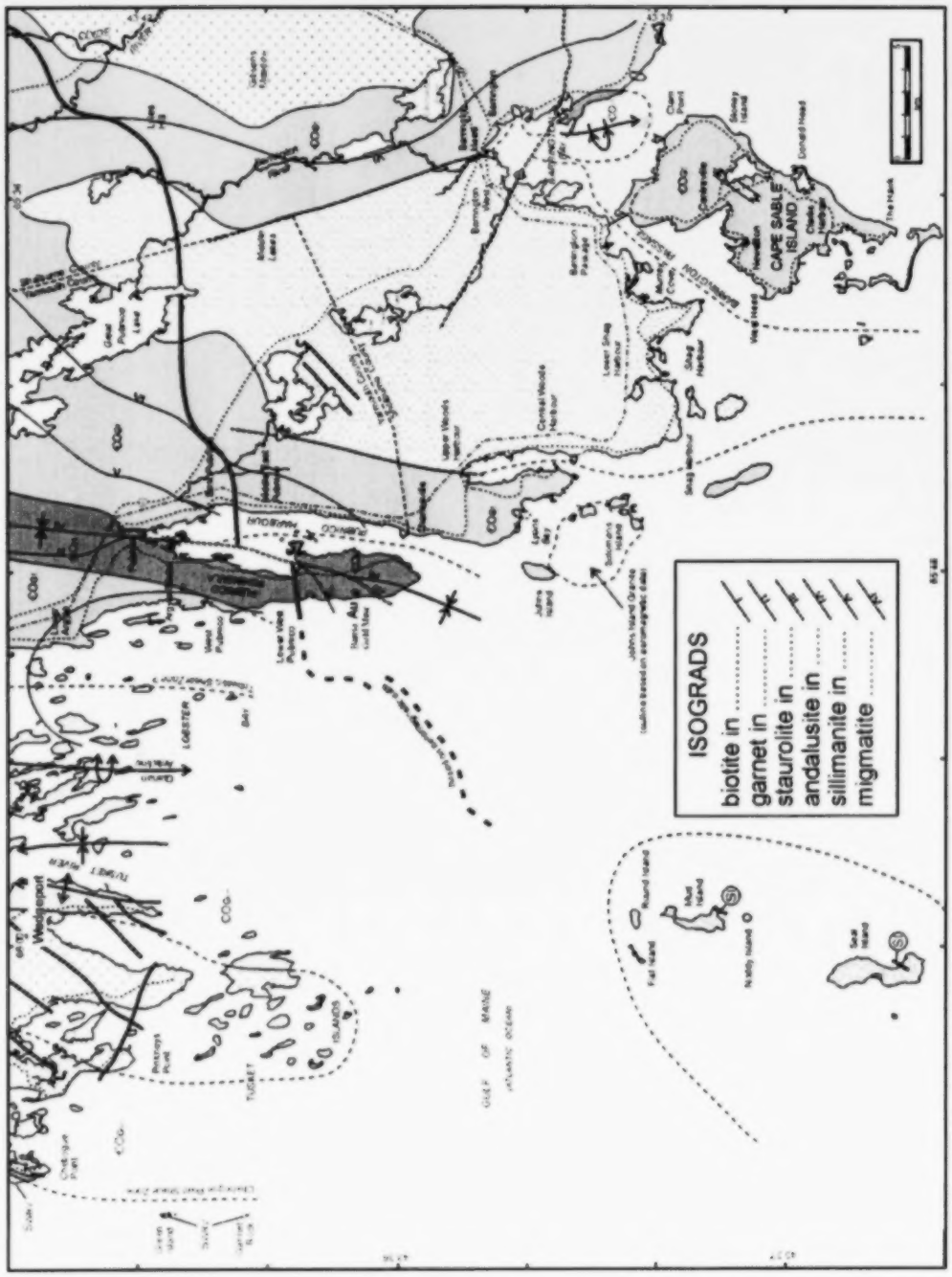
Goldenville Formation

In the map area to the north (Fig. 1), the Goldenville Formation was subdivided into two units termed the New Harbour and Tancook members, based on similarities to those units as defined farther to the northeast in Queens and Lunenburg Counties (O'Brien, 1986, 1988; Waldron, 1992). These divisions are also recognized in the present map area.

New Harbour Member

The New Harbour member occurs in the western half of the map area (Fig. 2), but is poorly exposed due to glacial overburden. Based on limited outcrop, the member consists of grey thick-bedded metasandstone that is locally interlayered with green, cleaved metasiltstone. Black slate interbeds are rare and everywhere spotted with biotite. The metasandstone is light grey, thickly bedded, and typically contains abundant elliptical calc-silicate lenses. The calc-silicate lenses are flattened parallel to bedding and elongated parallel to the intersection lineation (see structural section). Despite the obvious structural overprinting, original sedimentary structures are common, which aids in determining stratigraphic tops. These observations are consistent with those observed in this member to the north (White and King, 2002). On the western margin of the map area, the New Harbour member is conformably overlain by the Tancook member at Chebogue Point. The eastern contact is not exposed because the contact is presumed to be





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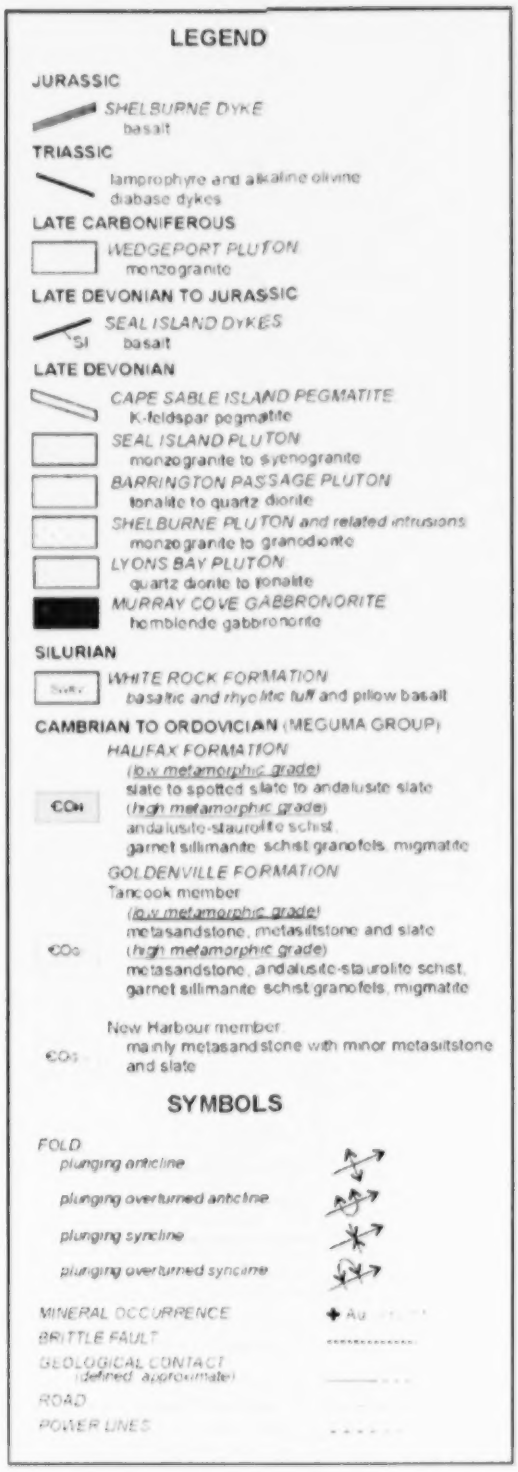

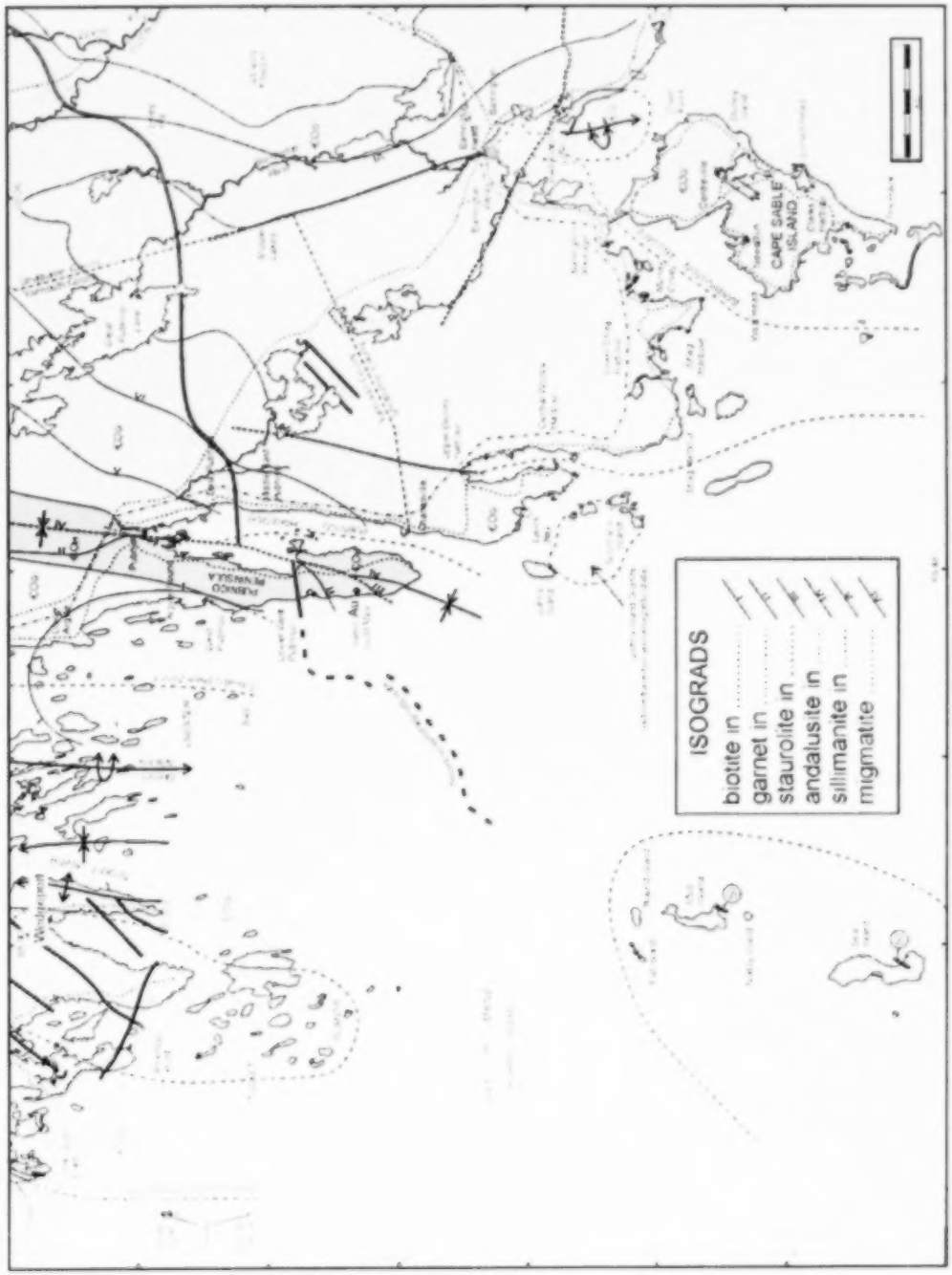

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underwater in Lobster Bay (Fig. 2).

Tancook Member

The Tancook member occurs mainly in the eastern half of the map area (Fig. 2), with a thin (< 100 m wide) part of the unit exposed in the west at Chebogue Point. In areas of low metamorphic grade, the Tancook member is typically composed of green, rhythmically laminated, cleaved metasiltstone and black slate, interlayered with laminated metasandstone in the proportion of about 50/50. As in the New Harbour member, calc-silicate nodules are very common in the metasandstone.

Stratigraphically above the Tancook member at Chebogue Point is a narrow (<100 m wide) unit of grey-green, well-laminated metasiltstone to slate. No metasandstone is associated with this unit, which is locally kinked and deformed, with boudinaged quartz veins. Along strike to the north this unit disappears, likely as a result of deformation related to the Chebogue Point shear zone. Although this unit was assigned to the Bloomfield member (basal part of the Halifax Formation) by White *et al.* (2001), it more closely resembles the Tancook member and is, therefore, included with it here.

At higher metamorphic grade, around the plutons to the east, the more pelitic beds in the Tancook member are composed of garnet-sillimanite schist/granofels and migmatite, similar to what was observed in the map area to the north (e.g. White and King, 2002). The spectacular development of garnet-sillimanite schist and granofels, however, with garnet crystals up to 2 cm in diameter adjacent to the Barrington Passage Pluton to the north, was not observed in the present map area.

Migmatitic rocks are more abundant in the present map area than to the north. They are characterized by dark grey fine-grained paleosomes with neosomes containing leucocratic medium-grained leucosomes and dark grey melanosomes. The leucosomes have quartzofelspathic compositions, whereas the melanosomes are mainly biotite and sillimanite. Small idioblastic red-brown garnet porphyroblasts occur in the melanosomes, but are generally absent in the leucosomes. Xenoblastic cordierite occurs in the melanosomes and locally in the leucosomes. Thick metasandstone beds are present and locally primary sedimentary features are preserved. The beds typically display "pinch and swell" textures and are commonly boudinaged parallel to the migmatitic foliation/layering.

Halifax Formation

Rocks typical of the Halifax Formation are exposed in three areas: (1) Chebogue Point, (2) Pubnico Peninsula and (3) east side of Barrington Bay (Fig. 2). The Halifax Formation at Chebogue Point consists of a fault-bounded unit of black to rust-brown slate with minor metasandstone laminations and lenses. It locally contains abundant pyrite and pyrrhotite. This unit is typical of the Cunard Formation in southwestern Nova Scotia (White *et al.*, 1999, 2001; Horne *et al.*, 2000). On the west side of Pubnico Peninsula, the Halifax Formation consists of rust-brown to grey slate that locally contains calc-silicate nodules and abundant pyrite and pyrrhotite. With an increase in metamorphic grade toward the east, the slates become increasingly andalusite-rich and form a wide band of chiastolite-bearing slates. On the east side of the peninsula, staurolite-andalusite schist and granofels are common. Along the east side of Barrington Bay, the Halifax Formation consists of coarse-grained muscovite-biotite schist and migmatite.

Although these higher metamorphic grade rocks are lithologically identical to those in the Tancook member, the lack of any substantial metasandstone beds suggests they belong to the Halifax Formation. The Cunard member is easily recognized at Chebogue Point, but because of the higher grade of metamorphism elsewhere in the map area it is more difficult to subdivide. As in the map area to the north, the Halifax Formation cannot be subdivided in the present map area.

White Rock Formation

The White Rock Formation is exposed only in the extreme western margin of the map area at Chebogue Point and on Green Island and Gannet

Rock (Fig. 2). Here the metavolcanic rocks consist of mafic lithic tuff with minor mafic ash beds, tuffaceous sandstone, and a distinctive felsic crystal tuff layer. Locally the mafic lithic tuff has a carbonate matrix. On Gannet Rock spectacular mafic pillow basalt is exposed. Primary volcanic textures are common and suggest stratigraphic tops to the east, which confirms the structural observations (bedding/cleavage relationship and fold asymmetry) on the islands. This unit corresponds to Unit 6 of White *et al.* (2001) and MacDonald *et al.* (2002), and corroborates the non-syncline model for the White Rock Formation (e.g. MacDonald *et al.*, 2002). Geochemistry of mafic volcanic rocks in the White Rock Formation indicate an alkalic affinity and a within-plate tectonic setting, and the felsic volcanic rocks have some characteristics similar to within-plate A-type granites (MacDonald, 2000; MacDonald *et al.*, 2002).

Intrusive Rocks

Introduction

Four major plutons occur in the map area: Barrington Passage, Shelburne, Seal Island and Wedgeport (Fig. 2). Smaller, minor intrusions occur in the metasedimentary rocks around the Barrington Passage Pluton (Fig. 2) and based on petrological evidence appear to be related to either the Barrington Passage or Shelburne plutons (e.g. Rogers, 1988). One minor intrusion, the Lyons Bay Pluton (Rogers, 1988), is mineralogically distinct from the rest. With the use of second derivative aeromagnetic data (King, unpublished data) and recent exposures of bedrock created by quarry and logging activities, both the shape and distribution of these plutons have been modified.

Barrington Passage Pluton

The Barrington Passage Pluton (BPP) (Taylor, 1967) occurs in the eastern part of the map area (Fig. 2) and was extensively studied by Rogers (1988). The pluton consists of grey, medium-grained, strongly foliated to equigranular biotite tonalite gradational to quartz diorite and granodiorite. Pegmatite is rare. Although amphibole was reported to occur by de Albuquerque (1979), none was observed in the tonalite during this study or the study by Rogers (1988). However, minor amphibole occurs in mafic enclaves and has been dated by the $^{40}Ar/^{39}Ar$ method (Reynolds *et al.*, 1987; see section on age). Mapping during the past summer has shown that the southern part of the BPP is not continuous with the northern part (cf. Rogers, 1986, 1988). The northern pluton, termed the Quinan Pluton by Reynolds *et al.* (1987), is more granodioritic in composition (Taylor, 1967) and appears to resemble rock types in the Shelburne Pluton. The eastern and western contacts of the BPP are faults (Fig. 2). The northern contact is well exposed on islands in Great Pubnico Lake and is clearly intrusive, with abundant tonalite dykes and sills intruding schist and migmatite of the Tancook member.

Locally the tonalite has layering defined by alternating biotite-rich and poor-bands, probably related to magma flow. It also exhibits a moderate to very strong tectonic foliation resulting from parallel alignment of biotite, and a lineation defined by elongate feldspar, quartz, and/or lens-shaped biotite aggregates. The tectonic foliation is generally parallel to the flow foliation. Small-scale isoclinal folds in the layering and boudinaged mafic enclaves are locally well developed. Toward the centre of the pluton, the "flow" foliation is locally preserved but the tectonic foliation is generally absent.

A black massive body of medium-grained gabbronorite is exposed along the coast and islands in the Murray Cove area (Fig. 2), and was termed the Murray Cove Diabase by Rogers (1988) and the Attwoods Brook Gabbronorite by Tate (1995). Contacts with the adjacent BPP were not observed during this study. Taylor (1967) and Rogers (1988), however, noted that the gabbronorite is intruded by tonalite and pegmatite dykes related to the BPP, and therefore interpreted the body as a xenolith. Based on textural and mineralogical evidence, subsequent workers demonstrated that the gabbronorite is more likely synplutonic with the BPP (e.g. Gallant, 1991; Tate, 1995; this study).

The irregular contact and the presence of numerous garnet-sillimanite schist/granofels

xenoliths in the northern (Quinan) pluton was considered by Rogers (1986) and White and King (2002) to indicate a shallower level of erosion compared to the southern part. However, if the northern part is a separate pluton, it may have intruded at a higher level in the crust than its southern counterpart. A higher level of intrusion suggests higher fluid/water content in the northern part and helps to explain the varied texture in the granitoid rocks and abundant pegmatite and aplite compared to the southern part. It may also explain the lack of abundant coarse-grained garnet-sillimanite schist/granofels around the southern pluton. Further studies are needed to quantify these observations.

As summarized by White and King (2002) and references within, the BPP has an age of ca. 373 Ma and based on geochemistry was derived from an "S-type" magma of intermediate composition in a syn-collisional setting. Some characteristics of the BPP, however, are similar to those of volcanic-arc granites and a subduction setting cannot be discounted.

Shelburne Pluton

The Shelburne Pluton (Taylor, 1967) occurs along the extreme eastern margin of the map area (Fig. 2). It is poorly exposed but clearly indicated on areomagnetic data (King unpublished data) as magnetic "lows". Like the BPP, the Shelburne Pluton was extensively studied by Rogers (1988), and Rogers and Barr (1988). In the map area the pluton is composed of moderately foliated, pale grey, medium-grained, bioitite- and muscovite-bearing monzogranite. A small body of massive, medium- to coarse-grained diorite (Birchtown Diorite of Rogers, 1988) outcrops within the monzogranite. Based on the presence of granitic dykes and pegmatites from the Shelburne Pluton in the diorite, Rogers (1988) and Tate (1995) considered this body to be xenolithic in origin. The diorite has yielded U-Pb (zircon) ages of ca. 376 Ma (Tate, 1995; Currie *et al.*, 1998). On Johns and Solomans islands outcrops of two-mica granite exist that are similar to the Shelburne Pluton. Based on aeromagnetic data these outcrops represent the surface exposure of a much larger unexposed body. As summarized by White and King (2002), the Shelburne Pluton has an age of ca. 372Ma and may have been derived from a felsic "S-type" magma in a syn-collisional setting.

Seal Island Pluton

The Seal Island Pluton (Rogers, 1988) outcrops on Seal Island and adjacent islands 30 km west of Cape Sable Island (Fig. 2). It consists of coarse-grained to porphyritic monzogranite gradational to syenogranite. Contacts with country rocks were not observed but the presence of numerous metasand-stone and hornfels xenoliths suggests that it intruded rocks of the Meguma Group. Rogers (1988) mapped a systematic east-west mineralogical and modal variation across the islands from muscovite syenogranite in the west, to muscovite-biotite monzogranite in the centre, and biotite monzogranite to the east. Every outcrop is cut by aplite dykes and quartz veins.

A weak foliation is present in most samples and defined by parallel alignment of biotite and muscovite. Steep, north-northeast-trending, narrow shear zones (< 50 cm wide) are common, but the sense of shear is unknown. A distinctive feature of the pluton is the abundance of tourmaline patches and layers, up to 2% of the rock (e.g. Taylor, 1967). The age of the Seal Island Pluton is not known but is likely ca. 373 Ma, based on its textural and mineralogical similarities to the South Mountain Batholith.

Wedgeport Pluton

The Wedgeport Pluton (Taylor, 1967) is poorly exposed in the southwestern part of the map area and is the focus of a B.Sc. Honours thesis by N. MacLean at Acadia University. The pluton consists mainly of unfoliated, medium- to coarse-grained equigranular monzogranite that is in places garnetiferous (Goose Bay granite of Chatterjee and Keppie, 1981). Enclaves of biotite-rich granodiorite and coarse-grained granitic porphyry occur locally, as well as convolute compositional banding possibly related to magmatic flow near contacts with the country rock. Aplitic, pegmatitic, and mafic dykes are present locally. A narrow contact metamorphic aureole of garnet-bearing hornfels occurs on the exposed western margin of the

pluton. Here the contact is concordant but dykes of granite extend into the hornfels. The location of the eastern margin of the pluton is based on aeromagnetic data and the presence of small granitic dykes, presumably related to the pluton, in outcrops of the Goldenville Formation. Preliminary chemical data suggest that the pluton is a within-plate A-type granite, derived from melting of continental crust (MacLean *et al.*, 2003). Based on a zircon U-Pb age of 316 Ma (Cormier *et al.*, 1988) it appears to be the youngest granitic pluton in the Meguma Terrane.

Lyons Bay Pluton

The Lyons Bay Pluton (Rogers, 1988) outcrops south of Charlesville on the north shore of Lyons Bay (Fig. 2). The pluton is hornblende-bearing and varies in composition from quartz diorite to tonalite (Rogers, 1988). The centre of the pluton is medium-grained and generally equigranular, but toward the margins the pluton becomes increasingly foliated and blastomylonitic in texture. The contact with the adjacent migmatite of the Tancook member is clearly tectonic. Although outcrop is sporadic, second derivative aeromagnetic data (King, unpublished data) indicate that the pluton is a small, north-south elliptical body, confirming the interpretation of Rogers (1988). The intrusive age of this pluton is unknown but hornblende from the unfoliated part of the pluton yielded an $^{Ar}40/^{39}Ar$ plateau age of ca. 389 Ma (Dallmeyer and Keppie, 1987).

Pegmatite and Aplite Dykes

Pegmatite and aplite dykes occur throughout the area in all units, but are most commonly associated with the Shelburne Pluton. They are massive and unzoned, and consist of smoky quartz, white to pink perthitic feldspar, biotite and minor muscovite. Tourmaline is common with lesser amounts of garnet. Beryl is rare. An isolated, northeast-trending pegmatite dyke is exposed on Cape Sable Island (Fig. 2). It is 100 m wide and over 1 km in length, and composed mainly of granophyric K-feldspar and quartz (Rogers, 1988). Aplite dykes are commonly associated with the Shelburne Pluton and also occur as small lenses in pegmatite. They are typically equigranular and consist of feldspar, quartz, muscovite and garnet. Locally pegmatite and aplite are foliated parallel to regional fabrics.

Mafic Dykes

As noted in mapping to the north (White and King, 2002), pre-Late Devonian mafic dykes and sills are noticeably absent in the Goldenville and Halifax formations southeast of the Chebogue Point shear zone compared to the area to the northwest. However, Early Mesozoic lamprophyre and alkaline olivine diabase dykes occur in the western part of the map area (Pe-Piper and Reynolds, 2000). The dykes are poorly exposed, but were intersected in drillholes in the Goldenville Formation and Wedgeport Pluton in the Plymouth area (Cant *et al.*, 1978) and are evident on the basis of their magnetic response (King, unpublished data). Two thin (<2 m wide) mafic sills outcrop at Chebogue Point in metasiltstone of the Tancook member. The presence of olivine indicates that they belong to the alkaline olivine diabase dykes described by Pe-Piper and Reynolds (2000). The Early Jurassic tholeiitic Shelburne Dyke is poorly exposed, but based on areomagnetic data can be traced across the map area and offshore (Fig. 2).

Three narrow (<1.5 m wide) mafic dykes are exposed in the Seal Island Pluton on Mud and Seal islands (Fig. 2). The dyke on Mud Island is clearly intrusive into the granite with a well-developed chill margin (Rogers, 1988). The two dykes on Seal Island are intensely deformed as they occupy the north-trending shear zones; however, locally the original contacts are preserved and based on co-mingling textures the dykes appear to be syn-to late intrusive with the granite.

Deformation and Metamorphism

The Meguma Group was regionally deformed and metamorphosed during the Acadian Orogeny. Detailed $^{40}Ar/^{39}Ar$ studies on single grain muscovite and whole-rock samples from the Meguma Group indicate that regional greenschist facies metamorphism associated with the Acadian Orogeny occurred between ca. 388-406 Ma

(Muecke *et al.*, 1988; Hicks *et al.*, 1999; Muir, 2000). In the map area, regional scale north-trending folds with a well developed axial planar cleavage, and regional metamorphism that grades from greenschist facies in the west to amphibolite facies in the east, are generally attributed to the Acadian Orogeny.

Deformation

In the western part of the map area outcrop is sparse but sufficient such that combined with aeromagnetic data the spatial extent of structural features can be delineated. In the western part of the map area the New Harbour member is folded into a pair of upright, shallow north-plunging anticlines and synclines. These folds are the southerly extensions of the same structures mapped to the north (e.g. White and King, 2002). The larger Quinan anticline (White and King, 2002) also extends into the map area (Fig. 2) and is moderately inclined to the west and subhorizontal with an overturned western limb. The Halifax Formation along the Pubnico Peninsula also lies in a regional syncline, but is structurally complex because of younger faulting. In the Barrington Bay area the migmatitic Halifax Formation also lies within a syncline. Based on outcrop and areomagnetic patterns, this syncline is steeply inclined to the west and gently plunging to the south with an overturned eastern limb (Fig. 2).

Poles to bedding from the entire area define a moderately developed girdle distribution with a shallow, north-plunging fold axis (Fig. 3a), and poles to foliation indicate a near-vertical north-striking axial planar foliation (Fig. 3b). Minor F_1 folds are not common in the low-grade metamorphic rocks, but are more common in the higher grade schistose rocks. Although data show scatter, folds are generally upright and plunge gently to steeply north and south (Fig. 3a). Intersection lineations (L_1) (bedding/foliation) are somewhat scattered but are generally subhorizontal or gently plunge to the north or south (Fig. 3b). Elongate calc-silicate nodules typically are parallel to the intersection lineation. Like the minor folds, crenulation cleavages are more common in the schistose rocks and deform the schistosity and bedding. The crenulation cleavage appears to be a conjugate set, striking northeast and north with moderately dips, and the crenulation lineation is generally vertical and northeast-plunging (Fig. 3c).

Mineral lineations are locally evident in staurolite-andalusite schist as either elongated andalusite crystals or lens-shaped biotite. Mineral lineations are also well developed in the migmatitic rocks, and defined by elongate fibrolite mats or quartz rods and lens-shaped biotite and muscovite aggregates. These mineral lineations (L_{m1}), although somewhat scattered, have gently north-plunging orientations (Fig. 3d) and parallel the long axes of boudinaged metasandstone layers. A gently north-plunging mineral lineation (L_{m2}) is also well developed in the BPP (Fig. 3e) and defined by prismatic plagioclase crystals, quartz rods and elongate mafic boudins and enclaves, as previously documented in the pluton (Pignotta and Benn, 1999; White and King, 2002). Poles to magmatic layering in the BPP (Fig. 3e) form a girdle distribution around a shallow north-plunging axis, suggesting that the magmatic layering has been folded, as evident from small-scale isoclinal folds in the pluton (e.g. Pignotta and Benn, 1999). The calculated fold axis is identical in orientation to the mineral lineation in the BPP and the surrounding migmatite (Figs. d, e). In addition, meso- to macroscopic, upright isoclinal folds in the migmatite have identical gently north-plunging fold axes (Fig. 3f).

Petrographic investigations confirm the early interpretation that structures observed in the BPP are magmatic to high-temperature subsolidus fabrics related to syntectonic intrusion (e.g. Pignotta and Benn, 1999; White and King, 2002). This interpretation indicates a maximum principle stress parallel to the magmatic mineral lineation and parallel to the shallowly north-plunging, north-south regional fold axis. The structural and available geochronological data demonstrate that the BPP was emplaced and deformed along with the migmatite, schist, granofels and lower grade metamorphic rocks ca. 373 Ma, considerably later than the often cited ca. 400 Ma Acadian Orogeny (e.g. Keppie and Dallmeyer, 1995).

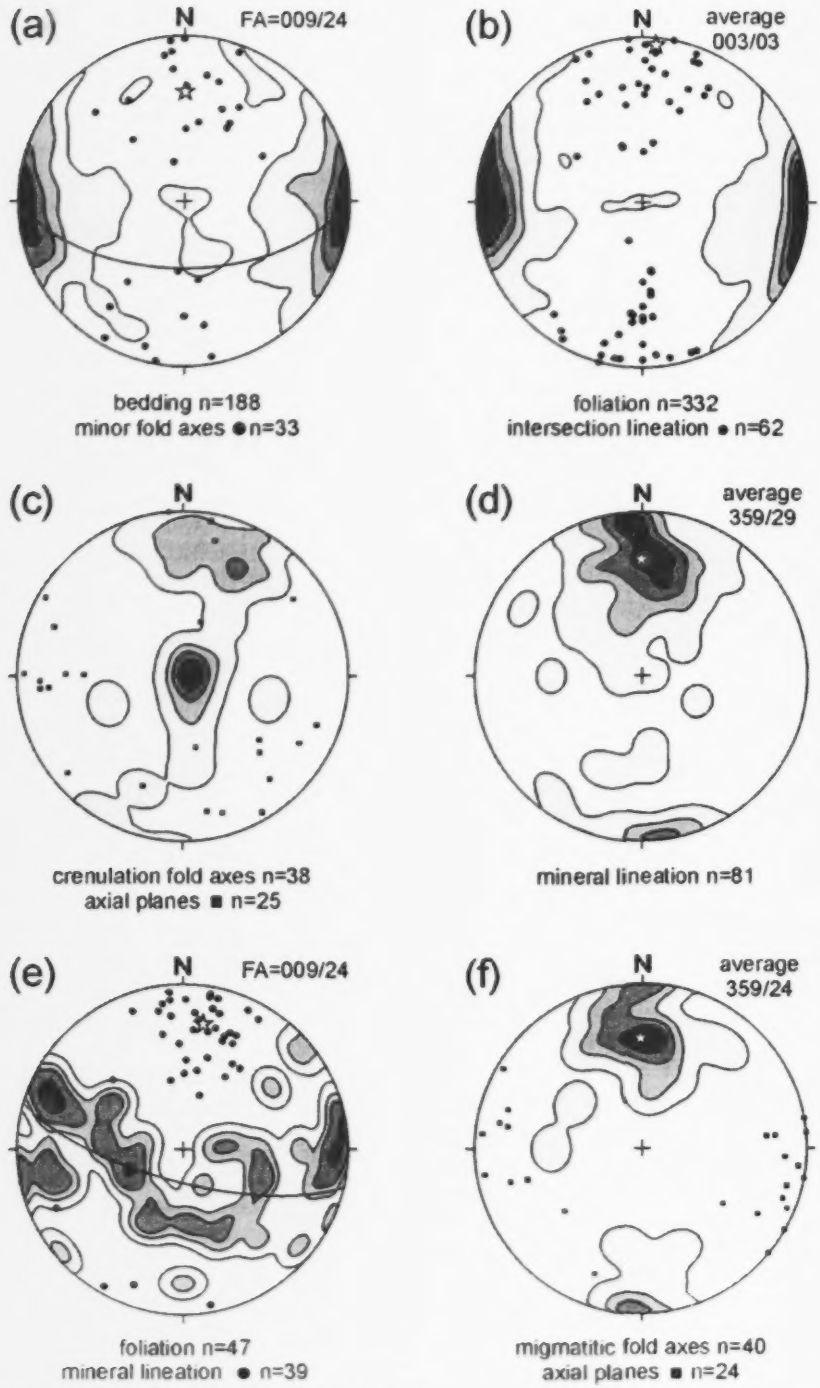

Figure 3. Equal area stereonets of structural data for the map area. (a) contoured poles to bedding and minor F_1 fold axes. (b) contoured poles to cleavage and schistosity and bedding-cleavage intersection lineations. (c) contoured crenulation lineations and filled squares represent poles to crenulation cleavage. (d) contoured mineral lineations in schist and migmatite. (e) contoured poles to banding/foliation in the Barrington Passage Pluton and associated mineral lineations. (f) contoured fold axes in migmatite and filled squares represent poles to axial planes. Contours on stereonets at 1, 3, 5, and greater than 7% per 1% area; darkest shading indicates highest contour area.

Shear Zones and Faults

Numerous shear zones have been well documented to the north and east of the map area (Giles, 1985; Smith, 1985; Keppie *et al.*, 1985; Hwang, 1990; White and King, 2002) and along the northwestern margin of the map area (White *et al.*, 2001). The southern extension of the Tobeatic Fault Zone (Giles, 1985) and Rushmere Lake shear zone (Smith, 1985) into the present map area was not confirmed. If present, the southern projection places these features underwater through Lobster Bay (Fig. 2). The Chebogue Point shear zone (Culshaw, 1994; Culshaw and Liesa, 1997) forms a wide north-south belt along the contact between the White Rock and Goldenville formations, incorporating the majority of the Halifax Formation (Fig. 2). Farther north, the shear zone juxtaposes chlorite/biotite-grade rocks of the Halifax and New Harbour member with staurolite-grade metamorphic rocks of the White Rock Formation (Hwang, 1985; Moynihan *et al.*, 2001, 2002). At Chebogue Point, kinematic indicators suggest west-side-up dip-slip motion (Culshaw and Liesa, 1997), whereas Dallmeyer and Keppie (1987) and Keppie and Dallmeyer (1995) argued for dextral shear. This zone is strongly overprinted by younger brittle deformation that locally obliterated earlier deformational textures.

High-strain zones are present in the schist, migmatite and granitic rocks of the Seal Island Pluton. Many are narrow features less than 50 cm in width. A major north-south shear zone is interpreted to underlie Pubnico Harbour. Schist along the east side of Pubnico Peninsula and migmatite along the Charlesville shore locally contain mesoscopic refolded isoclinal folds and strongly attenuated shallow south-plunging andalusite crystals interpreted to be the result of deformation. This shear zone is similar to those recognized to the east by Hwang (1990), which are also typically oriented north-south, post-date the metamorphic peak (e.g. Hwang, 1990), and have yielded $^{40}Ar/^{39}Ar$ muscovite ages of 335-320 Ma (Dallmeyer and Keppie, 1987). These ages are similar to those obtained in the Cape St. Marys and Cranberry Point shear zones, which yielded ca. 320 Ma muscovite ages (Culshaw and Reynolds, 1997). In addition, shearing in the ca. 316 Ma Wedgeport Pluton suggests that much of the ductile deformation in southwestern Nova Scotia may be of Carboniferous age.

Evidence for extensive low-grade deformation has been documented in Halifax Formation rocks along the western and southern coast of Pubnico Peninsula (e.g. Ross, 1985; Raeside and Jamieson, 1992). Here the banded slate contains shear bands, tightly folded bedding, layer parallel faults, and boudinaged sandstone and siltstone layers. In places the earlier isoclinal folds are refolded (e.g. Raeside and Jamieson, 1992). These structural features are overgrown by chiastolite crystals. In the coarse-grained andalusite schist and granofels units "millipede structures" are recognized in andalusite (Raeside and Jamieson, 1992). The age and sense of movement along this pre-porphryblastic shear zone are unknown.

Brittle faults are present throughout the map area. The Cunard member in the western part of the map area in the Chebogue Point shear zone (Fig. 2) is entirely fault-bounded (White *et al.*, 2001). The north-south Pubnico Harbour Fault offsets metamorphic isograds and juxtaposes garnet-grade slate on the west with andalusite schist on the east (Ross, 1985). Along with vertical movement, a significant amount of sinistral movement is suggested by the offset of the Shelburne Dyke and the presence of Z-shaped drag folds (e.g. Ross, 1985). Faults are inferred along the eastern and western margins of the BPP (Fig. 2) because of the strong linear aeromagnetic pattern. In addition, a northwest-trending fault, herein termed the Barrington Bay Fault (Fig. 2), is indicated by apparent offsets in aeromagnetic patterns. Senses of movement along these faults are not known.

Pseudotachylyte veins occur in many locations throughout the area. Many of the fractures that the veins occupy show evidence of microbrecciation along their margins and offsets up to 1-2 cm, suggesting that the veins represent *in situ* melts. They have been interpreted to be associated with shallow faulting and the intrusion of the BPP (Gareau, 1977).

Metamorphism

Several metamorphic zones have been determined in the map area (Bourque, 1985; Ross, 1985; Raeside and Jamieson, 1992), similar to those defined in the map area to the north (White and King, 2002). Chlorite-zone rocks have been recognized in the West Pubnico area (Raeside and Jamieson, 1992). In this zone the recognizable metamorphic minerals are chlorite and muscovite, which define the regional foliation. Locally spessartine garnet has been noted. Rocks assigned to the biotite zone occur in the western parts of the map area between Cheboque Point and Lower Argyle (Fig. 2). The biotite zone is characterized by the presence of prograde biotite, which gives the slate a more spotted appearance. A typical mineral assemblage is biotite + chlorite + muscovite + quartz + albite (e.g. Ross, 1985). Garnet zone rocks are similar to those in the biotite zone, except that they contain tiny porphyroblasts of garnet. The garnet zone grades into the chiastolite zone, which Ross (1985) considered to be a subzone of the garnet zone. Raeside and Jamieson (1992) considered the chiastolite-bearing slate to be part of the andalusite zone and possibly related to contact metamorphism by the BPP. This interpretation was based on the observed presence of chiastolite in the contact zone of the South Mountain Batholith. Rocks in the chlorite, biotite and garnet zones typically retain their original sedimentary textures, but their mineral assemblage is metamorphic.

The staurolite zone is recognized only on the southwestern tip of Pubnico Peninsula where it is in faulted contact with rocks of the garnet zone. The rocks in this zone represent the lowest metamorphic grade and display a coarse-grained schistosity defined by aligned biotite and muscovite. Most original sedimentary textures are obliterated. The typical mineral assemblage is staurolite + garnet + biotite + chlorite + muscovite + quartz + plagioclase (Ross, 1985). The andalusite zone (Fig. 2) is marked by the appearance of andalusite in schist. Andalusite typically forms very large crystals up to 40 cm long, which are typically randomly oriented on bedding planes but are locally elongate parallel to the regional fold axis. In addition to andalusite, staurolite and cordierite are locally abundant. In this zone cross-cutting andalusite veins are common.

The transition from the andalusite zone to the sillimanite zone (Fig. 2) is generally marked by the appearance of sillimanite as elongate fibrolite mats or prismatic crystals that, like some of the andalusite crystals in the andaluste zone, define a preferred orientation parallel to the regional fold axes. As metamorphic grade increases staurolite and andalusite disappear and garnet locally increases in size but still preserves spessartine-rich cores (Raeside and Jamieson, 1992). The garnet-sillimanite granofels zone around the Quinan Pluton to the north (White and King, 2002) is not present around the southern margin of the BPP.

Migmatite forms an aureole around the BPP up to 5 km in width (Fig. 2). Both anatectic and injection migmatite are present. Anatectic migmatite is developed in pelitic rocks and is commonly stromatic or opthalmitic with minor folded and nebulitic varieties (Bourque, 1985). Leucosome consists of quartz + feldspar + mica and rarely cordierite, and is granodioritic in composition, whereas both the melanosome and mesosome contain garnet + sillimanite + biotite + cordierite (Bourque, 1985; Raeside and Jamieson, 1992). The associated metasandstone layers contain the assemblage biotite + sillimanite + plagioclase + quartz (e.g. Raeside and Jamieson, 1992). Migmatitic rocks are not developed around the Shelburne Pluton.

Because migmatite borders the BPP, Taylor (1967) speculated that it was related to contact metamorphism by the BPP, but concluded that the regional metamorphic grade for the area was at least as high as the P-T conditions accompanying the emplacement of the granitic pluton. Bourque (1985) concluded that the combined effects of regional amphibolite-facies metamorphism and contact metamorphism resulted in migmatization. Based on structural observations the intrusion of the BPP accompanied or closely followed the peak of metamorphism.

The only clear evidence of contact metamorphism is associated with the Wedgeport Pluton. The pluton produced a narrow, 400 m contact metamorphic zone of spotted hornfels containing andalusite and cordierite superimposed on biotite zone assemblages (Cullen, 1983). Garnet is also present.

Age of Deformation and Metamorphism

A detailed $^{40}Ar/^{39}Ar$ study on single grain muscovite and whole-rock samples from the Meguma Group in the Digby area indicated that regional greenschist-facies metamorphism occurred ca. 400 Ma (Muir, 2000). This age is similar to $^{40}Ar/^{39}Ar$ ages reported elsewhere in the Meguma Group (405-390 Ma, Muecke *et al.*, 1988; 395-388 Ma, Hicks *et al.*, 1999) and was interpreted to date the timing of cleavage formation associated with the Acadian Orogeny. However, published U-Pb and $^{40}Ar/^{39}Ar$ data from the Pubnico-Shelburne area (Figs. 4, 5) suggest a more complex tectonic history for that area than previously thought (e.g. Taylor 1967; Rogers, 1988).

The only indication of a ca. 400 Ma metamorphic event is recorded in a poorly constrained $^{40}Ar/^{39}Ar$ hornblende total gas age of ca. 393 Ma (Figs. 4, 5) from a calc-silicate rock in the Goldenville Formation (Dallmeyer and Keppie, 1988) and a biotite total gas age of ca. 386 Ma (Fig. 4) from a staurolite schist (Muecke *et al.*, 1988). However, the biotite spectrum has a "saddle" distribution indicative of excess argon and the age should be considered a maximum.

Plutonic units in the map area have been generally well dated. Monazite, zircon and titanite from the BPP, Shelburne Pluton and Birchtown Diorite yielded U-Pb ages of ca. 377-362 Ma (Tate, 1995; Currie *et al.*, 1998; Keppie and Krogh, 1999) and there is some indication that older mafic intrusions exist in the area (e.g. ca. 389 Ma hornblende plateau age from undeformed diorite in the Lyons Cove Pluton; Dallmeyer and Keppie, 1987). Younger plutonism in the area is recorded in the U-Pb zircon age of ca. 316 Ma on the Wedgeport Pluton (Cormier *et al.*, 1988). A structural and magnetic fabric study of the BPP demonstrated that internal fabrics in the pluton parallel those in the country rocks, an observation interpreted to indicate that the pluton was emplaced and deformed during the Early Devonian Acadian Orogeny (Pignotta and Benn, 1999). Based on field relations that indicate that the pluton accompanied or closely followed the peak of metamorphism, however, it is likely that the ca. 373 Ma age for the BPP also dates the time of high-grade metamorphism in the map area.

Biotite and muscovite $^{40}Ar/^{39}Ar$ plateau and total gas ages from the plutonic units systematically increase from ca. 375 to 340 Ma (Figs. 4, 5). The easiest explanation for this feature is that it reflects post-intrusion cooling through the lower temperatures required for retention of argon in mica. A similar biotite and muscovite age pattern is present in the country rocks (Figs. 4, 5) and suggests similar cooling following the peak of regional and contact metamorphism.

Younger biotite and muscovite ages from the plutonic units form a peak distribution around ca. 315 Ma (Figs. 4, 5), suggesting that the mica ages were reset by some thermal event. This thermal event could be associated with intrusion of the ca. 316 Ma Wedgeport Pluton located farther to the west. If so, it would indicate the presence of several more ca. 316 Ma plutons at depth to account for the spatial distribution of these young mica ages in the plutons and in the country rocks. In addition, ca. 320 Ma ages have been acquired from recrystallized micas in ductile shear zones in the country rocks (Dallmeyer and Keppie, 1987; Keppie and Dallmeyer, 1995) and from shear zones farther west (Culshaw and Reynolds, 1997). These data suggest a recurrence of magmatism and deformation in the middle Carboniferous, probably related to the Alleghany Orogeny.

A third cluster is evident between ca. 290 to 250 Ma (Figs. 4, 5) from biotite and feldspar $^{40}Ar/^{39}Ar$ plateau and total gas ages in the plutonic units. Biotite ages in the country rocks also reflect this age range. It is unclear to what event these Permian ages could be attributed, but three biotite $^{40}Ar/^{39}Ar$ plateau ages of ca. 277, 269 and 258 Ma from the Wedgeport Pluton and associated contact metamorphic aureole (Fig. 4) suggest that they may be related to slow cooling following intrusion of the pluton. Dallmeyer and Keppie (1988) also recognized the lower biotite ages and suggested a ca. 290 Ma contact metamorphic event related to an offshore, subsurface pluton. This interpretation helps explain the lack of abundant muscovite ages in this range, and suggests that contact

metamorphic temperatures were sufficient to totally rejuvenate biotite but remained low enough to not reset muscovite.

The youngest hornblende and biotite $^{40}Ar/^{39}Ar$ plateau ages (ca. 231 to 222 Ma and ca. 209 to 203 Ma) in the area (Figs. 4, 5) are from the lamprophyre and alkaline olivine diabase dykes that occur in the western part of the map area (Pe-Piper and Reynolds, 2000). Although the younger dykes may be related to the much larger Shelburne Dyke and North Mountain Basalt, this magmatic activity does not appear to have been a thermal event significant enough to reset biotite and muscovite ages in the Meguma Group.

Economic Geology

Significant mineralization has been documented in the map area in association with the ca. 316 Ma Wedgeport Pluton. Shear-related veins of greisen and greisenized biotite granite contain a complex mineral association representing different episodes of mineralization. The ore minerals include cassiterite, wolframite, molybdenite, pyrite, pyrrhotite, arsenopyrite, silver-bearing sulphosalts, native bismuth and rare uranium molybdate (Wolfson, 1983; Chatterjee *et al.*, 1985). Shear joints and veins in the adjacent metasandstone typically contain pyrite, pyrrhotite, chalcopyrite, sphalerite, cassiterite, native silver and bismuth, and complex Ag-Sb-Bi sulphosalts. Because of hydrothermal alteration, the host rock and associated calc-silicate layers are mineralized. Skarnoid rocks contain pyrite, pyrrhotite, chalcopyrite, scheelite, malayite and possibly pabstite (Chatterjee and Keppie, 1981).

The only gold occurrence (Barrio Gold Mine) in the area is located along the west shore of Pubnico Peninsula (Fig. 2) and is described in the Nova Scotia Department of Natural Resources Mineral Occurrence Data Base for NTS map area 20P/12. Most of the exploration concentrated on extraction of placer gold from the beach, although trenching was conducted to locate the source.

Granitic pegmatite is locally common in the BPP and associated migmatite. Although not yet investigated, this may be similar to Li-Ta-Nb-Sn-bearing pegmatite exposed at Brazil Lake in the White Rock Formation (e.g. MacDonald *et al.*, 1992).

From an industrial minerals perspective, the map area holds great potential. Local communities are making use of sand and gravel to produce cement and asphalt. The BPP has been quarried for rip-rap used in building breakwaters. The pluton is also being evaluated as a source of crusted bedrock aggregate.

Summary

A major result of mapping during the summer of 2002 is the confirmation that stratigraphy in the Goldenville and Halifax formations is identical to that defined in the map area to the north (e.g. White and King, 2002). These units do not correlate with Meguma Group map units defined to the northwest (c.f. White *et al.*, 1999, 2000, 2001; Horne *et al.*, 2000). The change occurs across the Chebogue Point shear zone, and suggests that this structure is a major feature in southwestern Nova Scotia. As documented to the north, the stratigraphy is more similar to that defined farther northeast in the Meguma Group in Queens and Lunenburg Counties (O'Brien, 1986, 1988; Waldron, 1992).

Regional folds in the area are oriented north-south, plunge gently to the north, and have well developed axial planar cleavage.

The Barrington Passage Pluton can be divided into two separate and distinct bodies. The southern pluton consists dominantly of tonalite and following the definition of Taylor (1967) and Rogers (1988) is the actual Barrington Passage Pluton. The northern body, termed the Quinan Pluton (Muecke *et al.*, 1988), is mainly granodioritic in composition and appears to have intruded higher in the crust compared to the southern pluton.

Peak amphibolite-facies regional metamorphism appears to have coincided with intrusion of the Barrington Passage Pluton ca. 373 Ma. It is considerably younger than the ca. 400 Ma greenschist-facies regional metamorphism in the Meguma Group elsewhere in the Meguma Terrane.

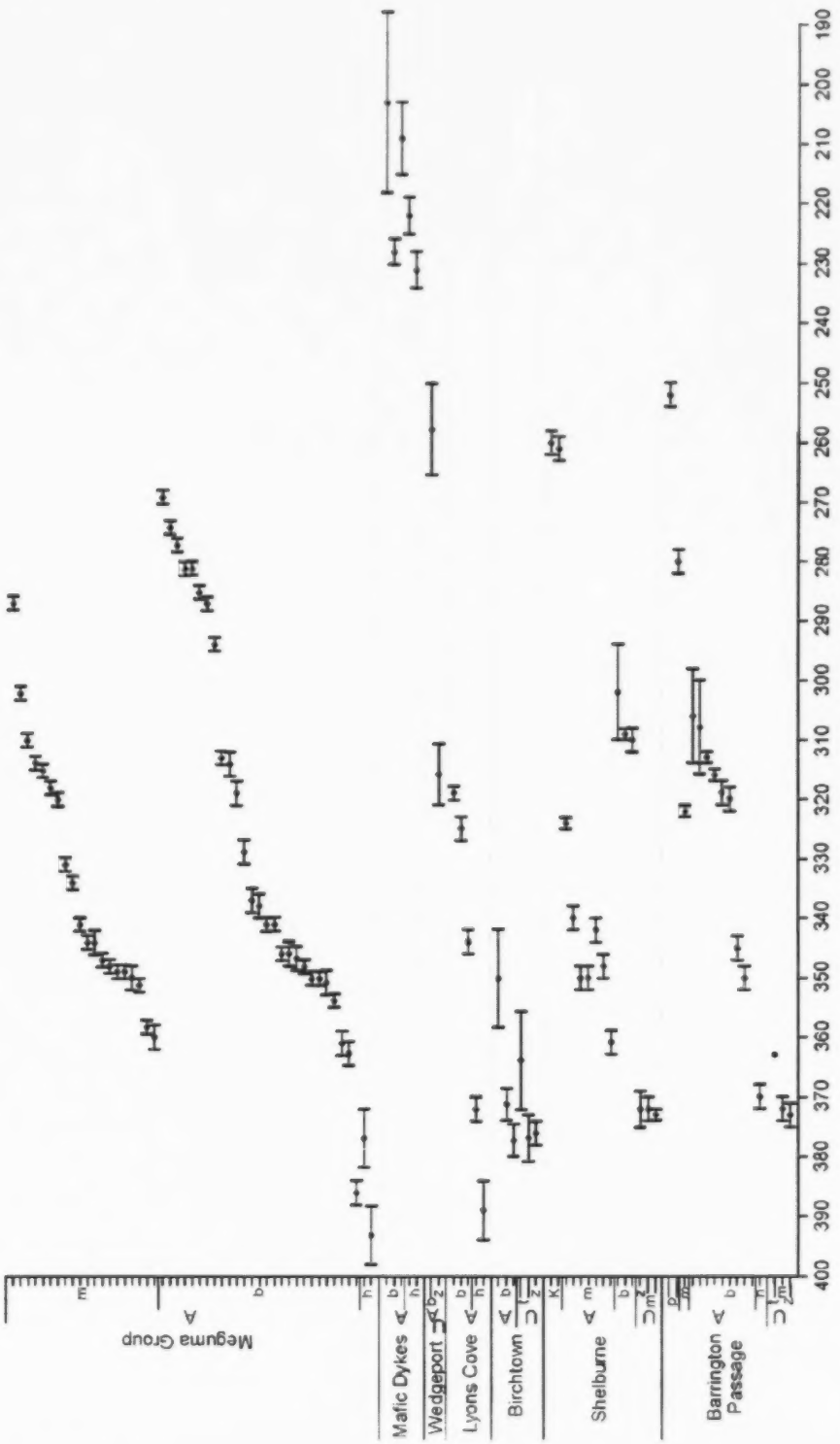

Figure 4. Compilation of published U-Pb and $^{40}Ar/^{39}Ar$ ages and errors from the Pubnico-Shelburne area. Abbreviations: U = U-Pb method (z = zircon, m = monazite, t = titanite); A = $^{40}Ar/^{39}Ar$ method (h = hornblende, b = biotite, m = muscovite, p = plagioclase, K = potassium feldspar). Data from Reynolds et al. (1981); Dallmeyer and Keppie, (1987, 1988); Reynolds et al. (1987); Cormier et al. (1988); Muecke et al. (1988); Keppie and Dallmeyer, (1995); Tate, (1995); Currie et al. (1998) Keppie and Krogh, (1999).

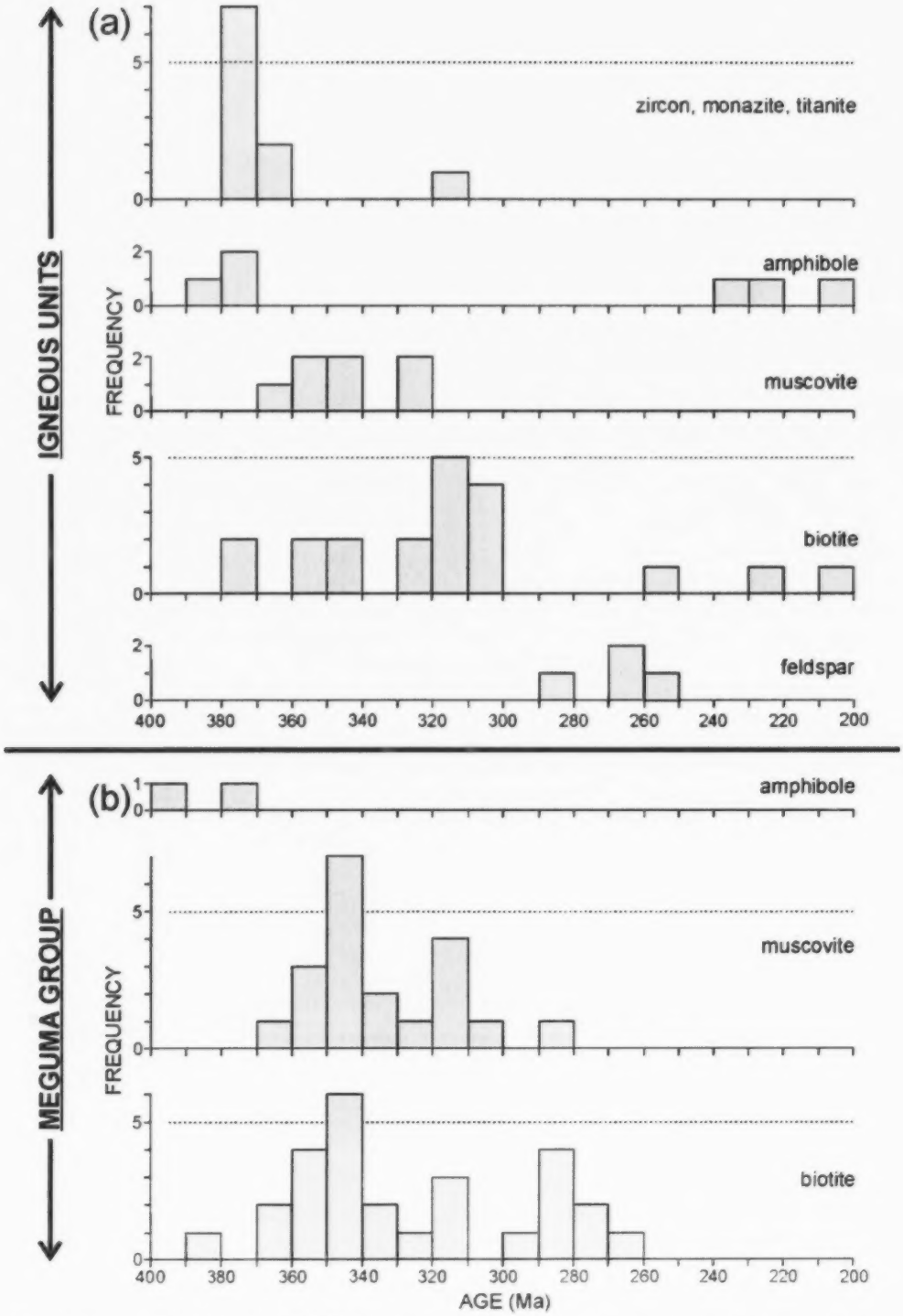

Figure 5. Histogram of U-Pb and $^{40}Ar/^{39}Ar$ ages from Figure 4 (a) ages from igneous units, (b) ages from metasedimentary rocks in the Meguma Group.

The Pubnico-Shelburne area experienced a younger tectonothermal event, apparently related to intrusion of the ca. 316 Ma Wedgeport Pluton. This event reset biotite ages in the area and appears to have been synchronous with ductile deformation related to the Alleghany Orogeny. Age data further suggest a tectonothermal event in the Permian that may have been be due to contact metamorphic effects of an unexposed pluton, or to slow cooling following intrusion of the Wedgeport Pluton.

The last geological event recorded by rocks in the area was intrusion of early Mesozoic lamprophyre and alkaline olivine diabase dykes. They did not have a thermal effect sufficient to reset biotite or muscovite ages in their host rocks.

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References

Bourque, A. D.1985: Migmatization and metamorphism associated with the Barrington Passage Pluton, Shelburne and Yarmouth Counties, Nova Scotia; BSc Honours thesis, Acadia University, Wolfville, Nova Scotia.

Cant, J. W., Fisher, D. F., Wilson, B. H., Dickie, G. B. and Sarkar, P. K. 1978: Report of exploration in Yarmouth County, Nova Scotia, (NTS 20/O and 20/P), May 1976 to April 1978; Shell Canada Resources Limited; Nova Scotia Department of Natural Resources Assessment Report A.R.-433144.

Chatterjee, A. K. and Keppie, J. D. 1981: Polymetallic mineralization in the endo- and exo-contact of the Wedgeport Pluton, Yarmouth County; *in* Report of Activities, 1980, ed. K. A. Mills; Province of Nova Scotia Department of Mines and Energy, Report 81-1, p. 43-46.

Chatterjee, A. K., Strong, D. F., Clarke, D. B. and Keppie, J. D. 1985: Geology and geochemistry of the Carboniferous Wedgeport Pluton hosting Sn-W mineralization; *in* Guide to Granites and Mineral Deposits of southwestern Nova Scotia, eds. A. K. Chatterjee and D. B. Clarke; Nova Scotia Department of Mines and Energy, Paper 85-3, p. 203-216.

Cormier, R. F., Keppie, J. D. and Odom, A. L. 1988: U-Pb and Rb-Sr geochronology of the Wedgeport granitoid pluton, southwestern Nova Scotia; Canadian Journal of Earth Sciences, v. 25, p. 255-261.

Cullen, J. D. 1983: Metamorphic petrology and geochemistry of the Goldenville Formation metasediments, Yarmouth, Nova Scotia; MSc thesis, Dalhousie University, Halifax, Nova Scotia.

Culshaw, N. 1994: A structural traverse from Yarmouth to Meteghan; Nova Scotia Department of Natural Resources Open File Report 94-025.

Culshaw, N. and Liesa, M. 1997: Alleghenian reactivation of the Acadian fold belt, Meguma Zone, southwest Nova Scotia; Canadian Journal of Earth Sciences, v. 34, p. 833-847.

Culshaw, N. and Reynolds, P. 1997: $^{40}Ar/^{39}Ar$ age of shear zones in the southwest Meguma Zone between Yarmouth and Meteghan, Nova Scotia; Canadian Journal of Earth Sciences, v. 34, p 848-853.

Currie, K. L., Whalen, J. B., Davis, W. J., Longstaffe, F. J. and Cousens, B. L. 1998: Geochemical evolution of peraluminous plutons in southern Nova Scotia, Canada-a pegmatite-poor suite; Lithos, v. 44, p. 117-140.

Dallmeyer, R. D. and Keppie, J. D. 1987: Polyphase late Paleozoic tectonothermal evolution of the southwestern Meguma Terrane, Nova Scotia: evidence from $^{40}Ar/^{39}Ar$ mineral ages; Canadian Journal of Earth Sciences, v. 24, p. 1242-1254.

Dallmeyer, R. D. and Keppie, J. D. 1988: Superposed Late Paleozoic thermal events in the southwestern Meguma Terrane, Nova Scotia; Maritimes Sediments and Atlantic Geology, v. 24, p. 157-169.

de Albuquerque, C. A. R. 1979: Origin of the plutonic mafic rocks of southern Nova Scotia; Geological Society of America Bulletin, v. 90, p. 719-731.

Gallant, G. K. 1991: Origin of the foliation in the Barrington Passage Pluton, southwest Nova Scotia; BSc thesis, Dalhousie University, Halifax, Nova Scotia.

Gareau, M. B. 1977: Pseudotachylytes of southwestern Nova Scotia; BSc thesis, Dalhousie University, Halifax, Nova Scotia.

Giles, P. S. 1985: A major post-Viséan sinistral shear zone-new perspectives on Devonian and Carboniferous rocks of southern Nova Scotia; *in* Guide to Granites and Mineral Deposits of southwestern Nova Scotia, eds. A. K. Chatterjee and D. B. Clarke; Nova Scotia Department of Mines and Energy, Paper 85-3, p. 233-264.

Hicks, R. J., Jamieson, R. A. and Reynolds, P. H. 1999: Detrital and metamorphic $^{40}Ar/^{39}Ar$ ages from muscovite and whole-rock samples, Meguma Supergroup, southern Nova Scotia; Canadian Journal of Earth Sciences, v. 36, p. 23-32.

Horne, R. J., White, C. E., Muir, C., Young, M. D. and King, M. S. 2000: Geology of the Weymouth-Church Point area (NTS 21A/05 and 21B/08, southwest Nova Scotia; *in* Report of Activities 1999, eds D. R. MacDonald and K. A. Mills; Nova Scotia Department of Natural Resources, Mines and Energy Branch Report ME 2000-1, p. 75-91.

Hwang, S. G. 1985: Geology and structure of the Yarmouth area, southwestern Nova Scotia; M.Sc. thesis, Acadia University, Wolfville, Nova Scotia.

Hwang, S. G. 1990: Structural and metamorphic geology of the Shelburne area, Nova Scotia; PhD thesis, University of New Brunswick, Fredericton, New Brunswick.

Keppie, J. D. and Dallmeyer, R. D. 1995: Late Paleozoic collision, delamination, short-lived magmatism, and rapid denudation in the Meguma Terrane (Nova Scotia, Canada): constraints from $^{40}Ar/^{39}Ar$ isotopic data; Canadian Journal of Earth Sciences, v. 32, p. 644-659.

Keppie, J. D. and Krogh, T. E. 1999: U-Pb geochronology of Devonian granites in the Meguma Terrane of Nova Scotia, Canada: Evidence for hotspot melting of a Neoproterozoic source; The Journal of Geology, v. 107, p. 555-568.

Keppie, J. D., Currie, K. L., Murphy, J. B., Pickerill, R. K., Fyffe, L. R. and St. Julien, P. 1985: Appalachian geotraverse (Canadian Mainland); Geological Association of Canada Excursion 1.

MacDonald, M. A., Boner, F. J. and Lombard, P. A. 1992: Multi-media detailed geochemical study of the Brazil Lake pegmatites, Yarmouth County, Nova Scotia; Nova Scotia Department of Natural Resources, Open File Report 92-016.

MacDonald, L. A. 2000: Petrology and stratigraphy of the White Rock Formation, Yarmouth area, Nova Scotia; M.Sc. thesis, Acadia University, Wolfville, Nova Scotia.

MacDonald, L. A., Barr, S. M., White, C. E. and Ketchum, J. W. F. 2002: Petrology, age, and tectonic setting of the White Rock Formation, Meguma terrane, Nova Scotia: evidence for Silurian continental rifting; Canadian Journal of Earth Sciences, v. 39, p. 1-19.

MacLean, N. J., Barr, S. M. and White, C. E. 2003: Petrology and tectonic setting of the Carboniferous Wedgeport Pluton, southwestern Nova Scotia: Presentation at the Northeastern Section, Geological Society of America 38th Annual Meeting, March 27-29; *in* Geological Society of America, Abstracts with Programs, v. 35, p. 54.

Moynihan, D. P., White, C. E. and Jamieson, R. A. 2001: Metamorphism and structure of the White Rock Formation in the Yarmouth area, Nova Scotia; *in* Mining Matters for Nova Scotia 2001, Opportunities for Economic Development, ed D. R. MacDonald; Nova Scotia Department of Natural Resources, Mines and Energy Branch Report ME 2001-2, p. 37.

Moynihan, D. P., White, C. E. and Jamieson, R. A. 2002: Metamorphism and structure of the White Rock Formation in the Yarmouth area, Nova Scotia; *in* Atlantic Geoscience Society Colloquium and Annual General Meeting, Program with Abstracts, p. 32.

Muecke, G. K, Elias, P. and Reynolds, P. H. 1988: Hercynian/Alleghanian overprinting of an Acadian Terrane: $^{40}Ar/^{39}Ar$ studies in the Meguma Zone, Nova Scotia; Chemical Geology, v. 73, p. 153-167.

Muir, C. M. 2000: An $^{40}Ar/^{39}Ar$ study of the Goldenville, Halifax, White Rock and Torbrook formations of the Digby area, southwest Nova Scotia; B.Sc. thesis, Dalhousie University, Halifax, Nova Scotia.

O'Brien, B. H. 1986: Preliminary report on the geology of the Mahone Bay area, Nova Scotia; in Current Research, Part A, Geological Survey of Canada, Paper 86-1A, p. 439-444.

O'Brien, B. H. 1988: A study of the Meguma Terrane in Lunenburg County, Nova Scotia; Geological Survey of Canada, Open File 1823.

Pe-Piper, G. A. and Reynolds, P. H. 2000: Early Mesozoic alkaline mafic dykes, southwestern Nova Scotia, Canada, and their bearing on Triassic-Jurassic magmatism; Canadian Mineralogist, v. 38, p. 217-232.

Pignotta, G. S. and Benn, K. 1999: Magnetic fabrics of the Barrington Passage pluton, Meguma Terrane, Nova Scotia: a two-stage fabric history of syntectonic emplacement; Tectonophysics, v. 307, p. 75-92.

Raeside, R. P. and Jamieson, R. A. 1992: Low-pressure metamorphism of the Meguma Terrane, Nova Scotia; Geological Association of Canada/ Mineralogical Association of Canada Joint Annual Meeting, June 1992; Field Excursion C-5: Guidebook.

Reynolds, P. H., Zentilli, M. and Muecke, G. K. 1981: K-Ar and $^{40}Ar/^{39}Ar$ geochronology of granitoid rocks from southern Nova Scotia: its bearing on the geological evolution of the Meguma Zone of the Appalachians; Canadian Journal of Earth Sciences, v. 18, p. 386-394.

Reynolds, P. H., Elias, P., Muecke, G. K. and Grist, A. M. 1987: Thermal history of the southwestern Meguma Group, Nova Scotia, from $^{40}Ar/^{39}Ar$ and fission track dating study of intrusive rocks; Canadian Journal of Earth Sciences, v. 24, p. 1952-1965.

Rogers, H. D. 1986: Igneous and metamorphic geology of Shelburne and eastern Yarmouth counties, Nova Scotia; Geological Survey of Canada, Open File Map 1374, Scale 1:50 000.

Rogers, H. D. 1988: Field relations, petrography, and geochemistry of granitoid plutons in the Shelburne area, southern Nova Scotia; Geological Survey of Canada, Open File 1835.

Rogers, H. D. and Barr, S. M. 1988: Petrography of the Shelburne and Barrington Passage plutons, southern Nova Scotia; Maritime Sediments and Atlantic Geology, v. 24, p. 21-31.

Ross, D. M. 1985: Structure and metamorphism of the Pubnico area, Yarmouth County, Nova Scotia; BSc Honours thesis, Acadia University, Wolfville, Nova Scotia.

Smith, P. K. 1985: Mylonitization and fluidised brecciation in southern Nova Scotia; *in* Mines and Minerals Branch, Report of Activities, 1984, eds. K. A. Mills and J. L. Bates; Nova Scotia Department of Mines and Energy, Report 85-1, p. 119-133.

Tate, M. C. 1995: The relationship between Late Devonian mafic intrusions and peraluminous granitoid generation in the Meguma Lithotectonic Zone, Nova Scotia, Canada; PhD thesis, Dalhousie University, Halifax, Nova Scotia.

Taylor, F. C. 1967: Reconnaissance Geology of Shelburne map-area, Queens, Shelburne, and Yarmouth Counties, Nova Scotia; Geological Survey of Canada Memoir 349.

Waldron, J. W. 1992: The Goldenville-Halifax transition, Mahone Bay, Nova Scotia: relative sea-level rise in the Meguma source terrane; Canadian Journal of Earth Sciences, v. 29, p. 1091-1105.

White, C. E. and King, 2002: Preliminary bedrock geology of the Tusket map area (NTS 20P/13), southwestern Nova Scotia; *in* Minerals and Energy Branch, Report of Activities 2001; Nova Scotia Department of Natural Resources, Minerals and Energy Branch, Report ME 2002-1, p. 141-158.

White, C. E., Horne, R. J., Muir, C., and Hunter, J. 1999: Preliminary bedrock geology of the Digby map sheet, southwestern Nova Scotia; *in* Minerals and Energy Branch, Report of Activities 1998; Nova Scotia Department of Natural Resources, Mines and Energy Branch, Report 98-1, p. 119-134.

White, C. E., Horne, R. J., Teniere, P. J., Jodrey, M. J. and King, M. S. 2001: Geology of the Meteghan River-Yarmouth area: a progress report on the Southwest Nova Scotia Mapping Project; *in* Minerals and Energy Branch, Report of Activities 2000; Nova Scotia Department of Natural Resources, Mines and Energy Branch, Report 2000-1, p. 95-111.

Wolfson, I. K. 1983: A study of the tin mineralization and lithogeochemistry in the area of the Wedgeport Pluton, southwestern Nova Scotia; MSc thesis, Dalhousie University, Halifax, Nova Scotia.

Gabbroic Intrusions in the Meteghan - Yarmouth Area (NTS 21A/04, 21B/01, 20P/13 and 20O/16) of the Meguma Terrane, Southern Nova Scotia

C. E. White, S. M. Barr[1] and R. C. Gould

Introduction

Gabbroic plutons and sills are known to occur in the Goldenville, Halifax and White Rock formations in the Meguma terrane of southwestern Nova Scotia (e.g. Taylor, 1967, 1969; Smitheringale, 1973). Recent fieldwork related to the Southwest Nova Scotia Mapping Project has documented the presence of several additional gabbroic intrusions, sills and amphibolite sheets in the area. Several of the intrusions are associated with a variety of mineral occurrences (Fig. 1), and some have been quarried for wharf and breakwater construction, and/or investigated for building stone potential.

Few petrological studies have been done previously on these gabbroic rocks (e.g. Calder, 1981; Calder and Barr, 1982). The purpose of this paper is to provide new information about the field relations and petrology of mafic intrusions in the area between Meteghan and Yarmouth, including the Mavillette, Nickersons Point and Wentworth Lake gabbro bodies, as well as gabbroic and amphibolitic sills in the Goldenville, Halifax, and White Rock formations (Fig. 1). The data are used to characterize and compare these varied mafic intrusions, and to interpret their chemical affinity and tectonic setting.

Field Relations and Petrography

Mavillette Gabbro and Associated Sills

Prior to this study, exposures of the Mavillette Gabbro were known only in and around an abandoned quarry on the east side of Highway #1 between Mavillette and St. Alphonse, Digby County (Fig. 2). The gabbro was interpreted to be a Silurian dyke intruded into the Halifax Formation, although the host rocks were not well exposed (Taylor, 1969; Calder, 1981; Calder and Barr, 1982; White *et al.*, 2001). Recent quarrying and logging activities in the area have uncovered additional outcrops of the gabbro and associated host rocks. These new exposures extend the gabbro to the west of Highway #1 (Fig. 2). They indicate that the gabbro intruded metavolcanic and metasedimentary rocks of the White Rock Formation, rather than the Halifax Formation, and that it forms a large semicircular body at the nose of a regional syncline. This interpretation of the shape of the body is consistent with high-resolution second derivative aeromagnetic data in the area (M. S. King, unpublished maps). In a new quarry in the gabbro west of Highway #1 (Fig. 2), extensive hematitic alteration was noted along a prominent fracture that contains a 5 cm-wide vein of asbestos-like material.

Numerous gabbroic sills in slate of the Halifax Formation along the coast to the northwest and in volcanic rocks of the White Rock Formation to the southeast (Fig. 2) are interpreted to be related to the Mavillette Gabbro. The sills range from 1 to 5 m in width and are typically boudinaged parallel to bedding/foliation (bedding and foliation are parallel in these areas), although they locally cross-cut the bedding/foliation at a low angle. Quartz and carbonate veins are abundant in the sills and adjacent slate, and the slate is generally bleached light grey and extensively altered.

The Mavillette Gabbro consists of dark green to grey leuco-gabbronorite to gabbronorite to mela-gabbronorite (Fig. 3). The texture is typically

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White, C. E., Barr, S. M. and Gould, R. C. 2003: *in* Mineral Resources Branch, Report of Activities 2002; Nova Scotia Department of Natural Resources, Report 2003-1, p. 147-162.

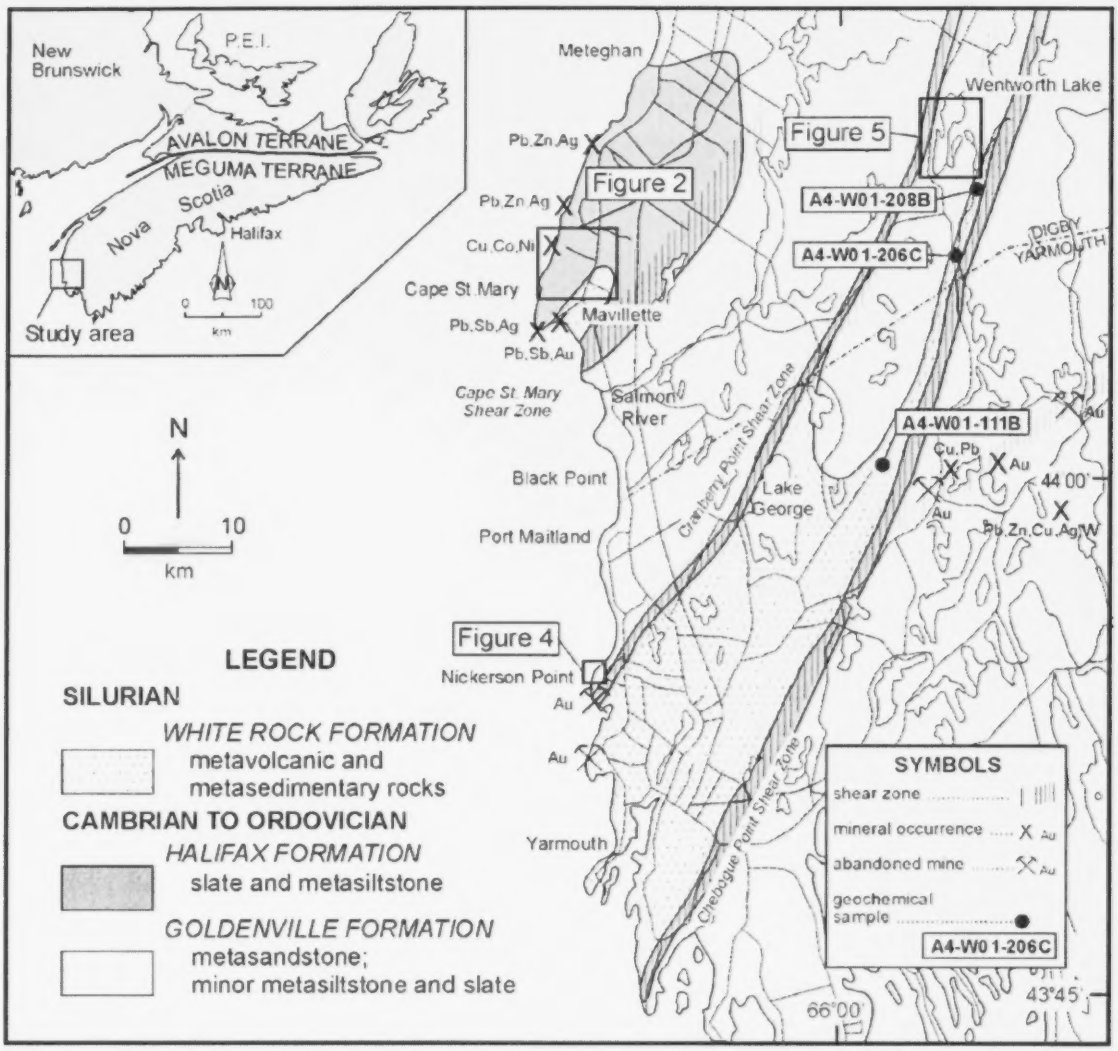
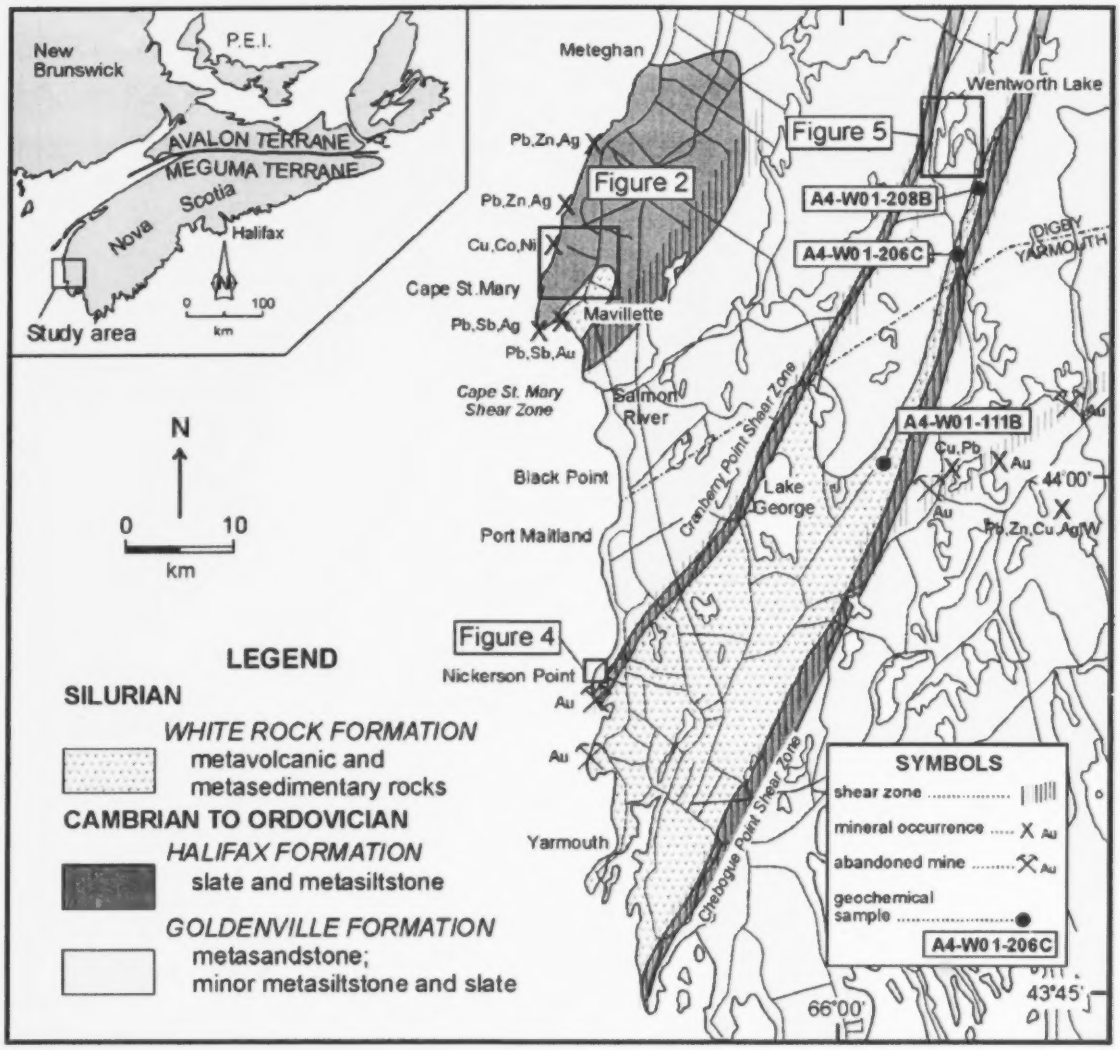


Figure 1. Simplified geology map of Meteghan - Yarmouth area of southwestern Nova Scotia showing locations of the

medium-grained and subophitic to ophitic, except near the margins of the body where it is fine-grained and intergranular. In some areas, the texture is porphyritic or pegmatitic, and in other areas it is foliated. Throughout the gabbro, leucocratic segregations with abundant quartz, plagioclase and K-feldspar are present and compositionally correspond to the monzonite described by Calder (1981) and Calder and Barr (1982). These leucocratic rocks were not sampled during this study. Porphyritic samples tend to be leuco-gabbronorite in composition, and correspond to the monzogabbro described by Calder (1981) and Calder and Barr (1982). The sills in the coastal section to the west, as well as the one to the southeast, consist of fine-grained gabbronorite with intergranular texture.

Petrographic examination of samples from the newly exposed western part of the Mavillette Gabbro suggests that it is similar to the eastern part of the body described by Calder (1981). The



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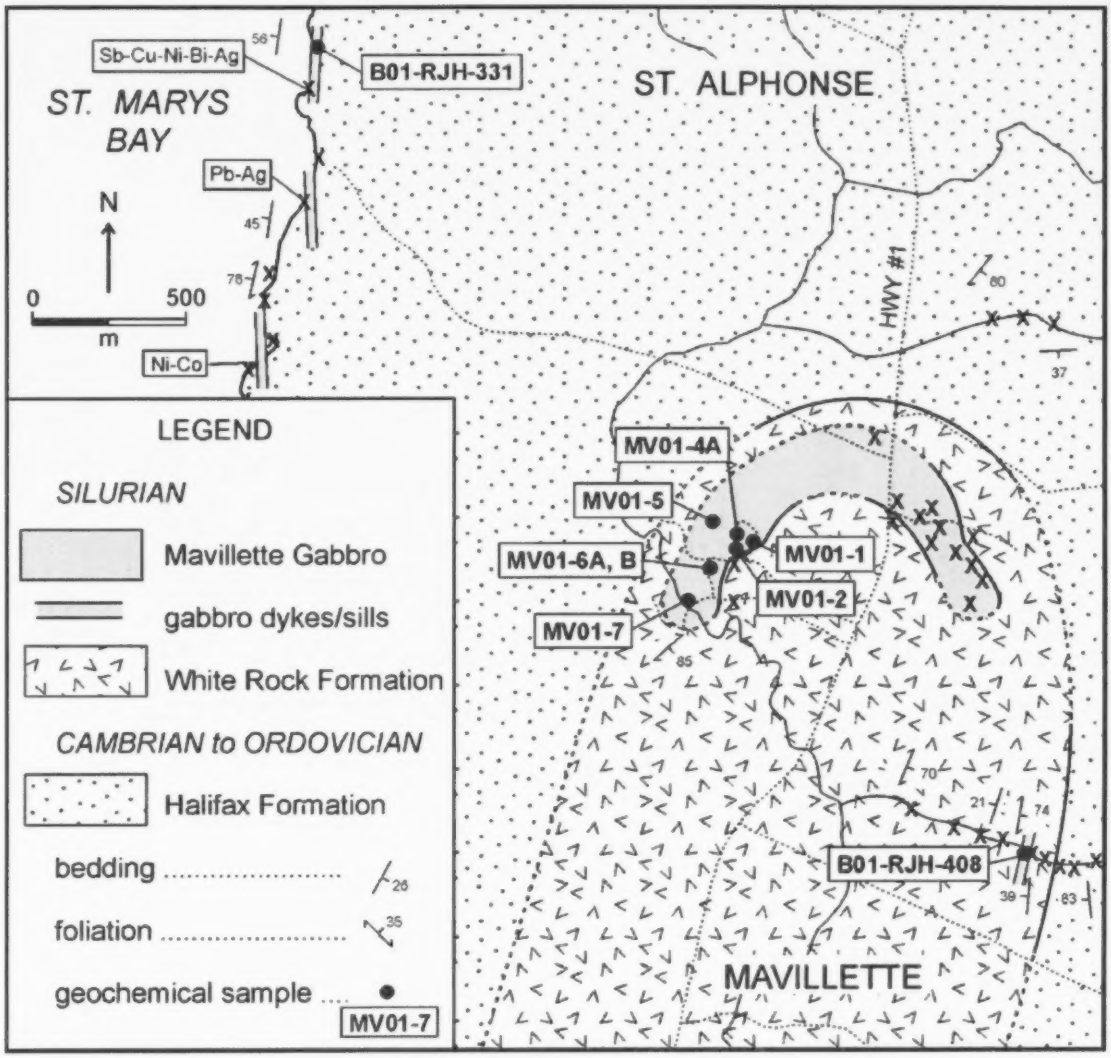

Figure 2. Simplified geology map of the Mavillette area showing geochemical sample locations.

samples consist predominantly of subhedral zoned plagioclase (52-68%) with composition (based on optical determinations) ranging from oligoclase to andesine, similar to compositions determined by electron microprobe analyses of plagioclase in samples from the eastern part of the gabbro (Calder, 1981; Calder and Barr, 1982). Most of the plagioclase is altered to saussurite or sericite and minor carbonate minerals. Clinopyroxene (26-39%) is generally subhedral and varies from inclusion-rich to inclusion-free. It is commonly rimmed by chlorite or a mixture of fibrous actinolite, epidote and calcite or blue-green amphibole. Trace amounts of biotite also occur along clinopyroxene rims or in the cores. Calder (1981) and Calder and Barr (1982) reported that the clinopyroxene is of augite composition. Fine- to coarse-grained opaque minerals (4-14%) are subhedral and exhibit spectacular skeletal textures in the sills. Mineral analyses indicate that ilmenite is the dominant phase, although minor amounts of magnetite, pyrite and pyrrhotite are present (Calder, 1982; Calder

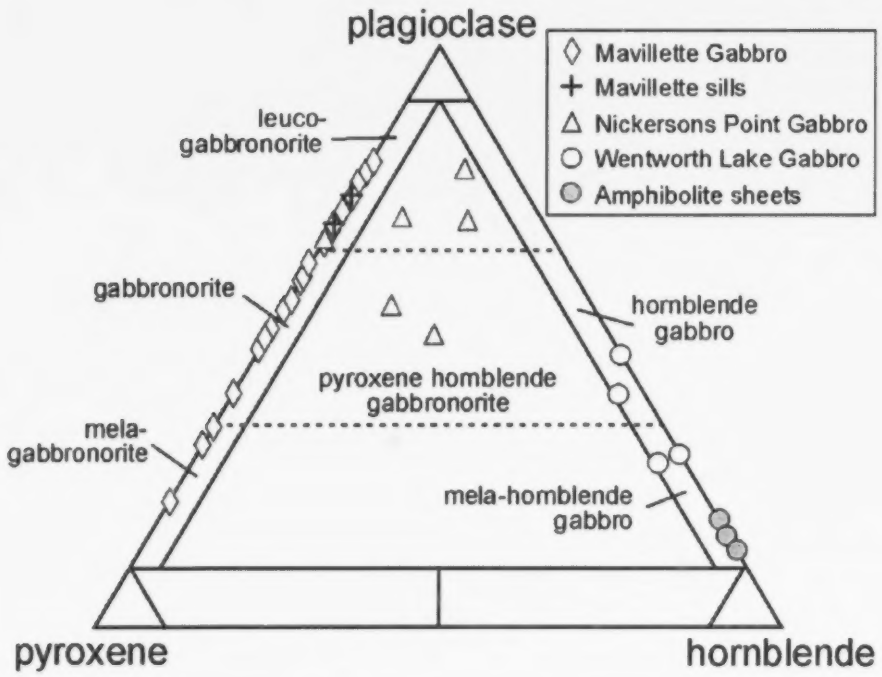

Figure 3. Streckeisen (1976) modal analysis diagram for gabbroic rocks that contain hornblende.

and Barr, 1982). Euhedral grains of apatite (1-5%) are enclosed in both plagioclase and augite. Mineral textures suggest the plagioclase, augite, ilmenite and apatite all crystallized simultaneously. Interstitial quartz (<3%) and K-feldspar (<1%) occur in some samples and appear to be secondary; however, more abundant quartz and K-feldspar were noted in samples termed monzonite and monzogabbro by Calder (1981) and Calder and Barr (1982) and may be primary minerals crystallized from late, more differentiated magma. The mineralogy of sills to the northwest and southeast is similar that of the main gabbro body.

Nickersons Point Gabbro

The Nickersons Point Gabbro outcrops on the coast at Nickersons Point between Port Maitland and Yarmouth, in Yarmouth County, and intrudes metasandstone of the Goldenville Formation (Figs. 1, 4). At the well exposed southern contact, the gabbro is fine-grained and locally contains xenoliths of metasandstone, and the adjacent metasandstone is recrystallized. At the northern contact the gabbro is slightly sheared and foliated but still displays a fine-grained chilled margin against the metasandstone. The western contact is concealed by water and the eastern contact by glacial overburden. Faribault (1920) considered the gabbro to be a small circular intrusion but did not speculate on its age. Taylor (1969) suggested that the intrusion, which he termed biotite diorite, is an east-trending dyke that cuts folded Goldenville Formation rocks, and therefore was emplaced after the Devonian Acadian Orogeny. Our observations are more consistent with the circular shape proposed by Faribault (1920), and the presence of a locally developed foliation indicates that the intrusion likely pre-dated the Acadian Orogeny, and is probably Silurian.

The Nickersons Point Gabbro consists of dark green to grey, medium- to locally coarse-grained, leuco-gabbronorite, leuco-pyroxene hornblende gabbronorite, and pyroxene hornblende gabbronorite (Fig. 3). Most of the intrusion is intergranular to rarely ophitic and is locally layered

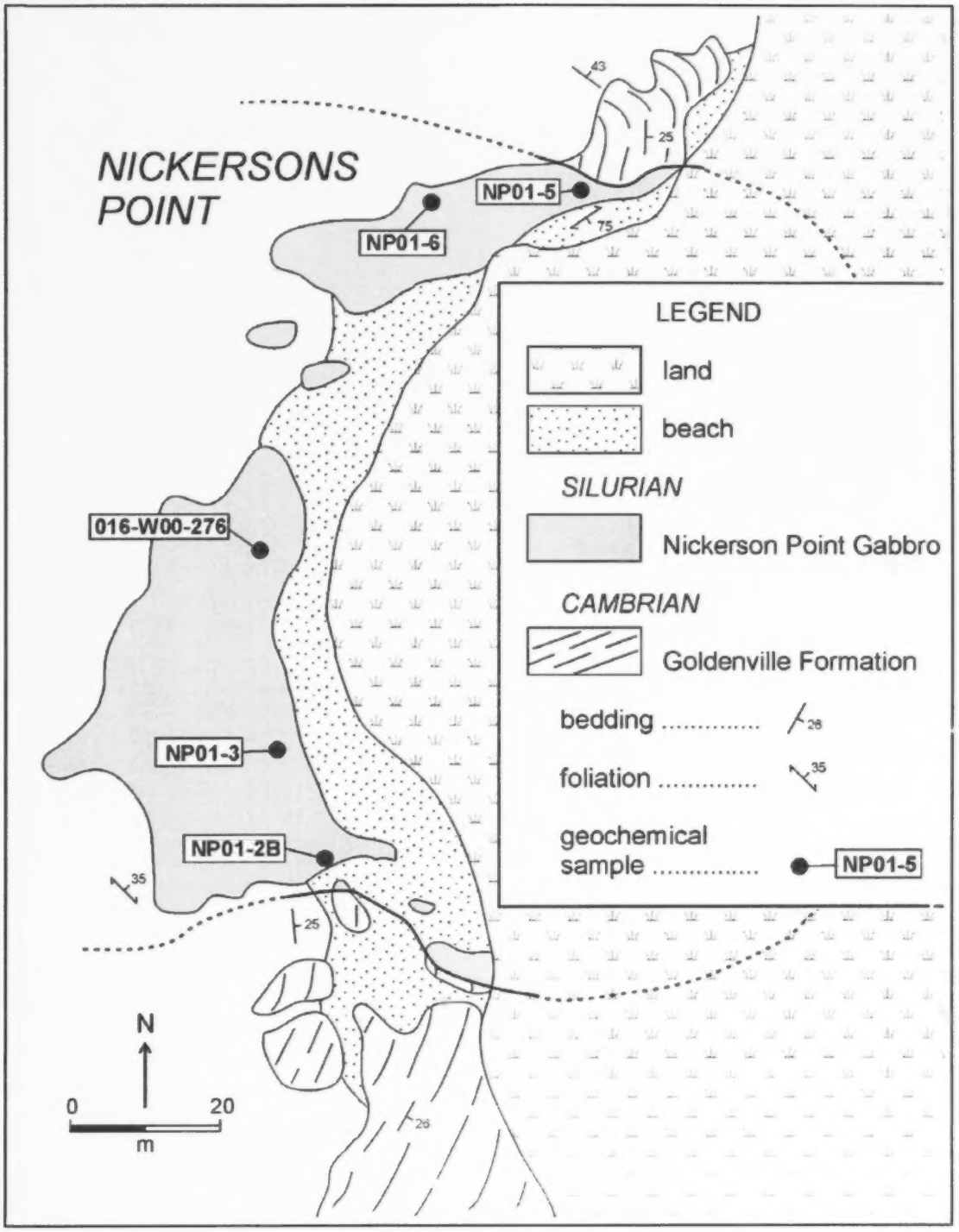

Figure 4. Simplified geology map of the Nickersons Point area showing geochemical sample locations.

with alternating plagioclase-rich and amphibolite-rich bands. Pods of amphibole+quartz to quartz+K-feldspar pegmatite and discontinuous small dykes of aplite are present. Quartz veining is common in the more foliated areas of the gabbro.

The Nickersons Point Gabbro, like the Mavillette Gabbro, consists predominantly of subhedral zoned plagioclase (43-60%) of labradorite to andesine composition. Most of the plagioclase is altered to saussurite or sericite. Clinopyroxene (7-34%) is generally subhedral and inclusion-free, although locally interstitial in a few samples. Clinopyroxene is commonly rimmed by chlorite or blue-green amphibole. In contrast to the Mavillette Gabbro, the Nickersons Point Gabbro contains abundant biotite (1-21%) and brown amphibole (1-20%). Both minerals occur as large discrete subhedral to anhedral grains, with abundant opaque mineral inclusions, and locally rimmed by chlorite or blue-green amphibole. Biotite is commonly kinked and amphibole locally contains clinopyroxene cores. Opaque minerals (< 4%) are subhedral and do not exhibit skeletal textures, in contrast to those in the Mavillette Gabbro, and have been interpreted to be magnetite (Taylor 1967). Euhedral grains of apatite (< 4%) are enclosed in all the mineral phases. Interstitial quartz (<10%) and K-feldspar (<1%) occur in some samples and are considered secondary.

Wentworth Lake Gabbro

Wentworth Lake Gabbro outcrops on a series of small islands in the centre of Wentworth Lake in Digby County (Figs. 1, 5). Although contacts with the surrounding metasandstone of the Goldenville Formation are not exposed, the outcrop distribution suggests that the intrusion is dyke-like and slightly discordant to the nose of a north-plunging regional anticline (Fig. 5). The intrusion was first described by Taylor (1969) as diorite similar in age to the Silurian White Rock Formation. He also noted the presence of a regional-trending schistosity in the "diorite". O'Reilly (1978) and Ham and MacDonald (1994) described the intrusion as dioritic and considered it middle Devonian or earlier in age. The rock is medium- to locally coarse-grained, equigranular and massive in appearance, and ranges in composition from melahornblende gabbro to hornblende gabbro (Fig. 3). However, locally the intrusion is mylonitic (schistosity of Taylor, 1969) with a moderately east-dipping foliation and a shallow, south-plunging stretching lineation (Fig. 5). Sense of movement appears to be to the north. Like the Nickersons Point and Mavillette gabbros, the Wentworth Lake Gabbro contains leucocratic patches and quartz veins that are locally deformed in the shear zone.

The Wentworth Lake Gabbro, in contrast to Mavillette and Nickersons Point gabbros, consists predominantly of subhedral pale green amphibole (38-57%) which is weakly zoned, typically inclusion-rich and commonly rimmed by fibrous actinolite. Locally, brown amphibole or clinopyroxene cores are present. Plagioclase (23-40%) is subhedral, of andesine composition and altered to saussurite or sericite. Biotite (3-16%) occurs in anhedral interstitial grains. In the mylonitic samples foliation is defined by alternating amphibole-rich and amphibole-biotite-rich bands. The lineation is defined by the preferred orientation of amphibole. Late actinolitic amphibole randomly overgrows the foliation. The mylonitic textures are better described as blastomylonite. Interstitial quartz (<10%) and K-feldspar (trace) occur in some samples and are considered secondary. Apatite is not common.

Amphibolite Sheets

Three newly discovered exposures of amphibolite associated with highly deformed tuffaceous metasandstone, felsic crystal metatuff, slate and quartzite extend the distribution of the White Rock Formation parallel to a belt of Halifax Formation to just south of Wentworth Lake (Fig. 1). The amphibolite is typically 1 to 2 meters wide, texturally homogeneous and boudinaged parallel to bedding/cleavage. Because the amphibolite is texturally homogenous, it is interpreted to have originated as a mafic intrusion. However, it is difficult to say if the three exposures intruded as dykes that were later transposed parallel to bedding/cleavage during metamorphism and shearing, or if they were intruded as sills; hence they are referred to here as "sheets".

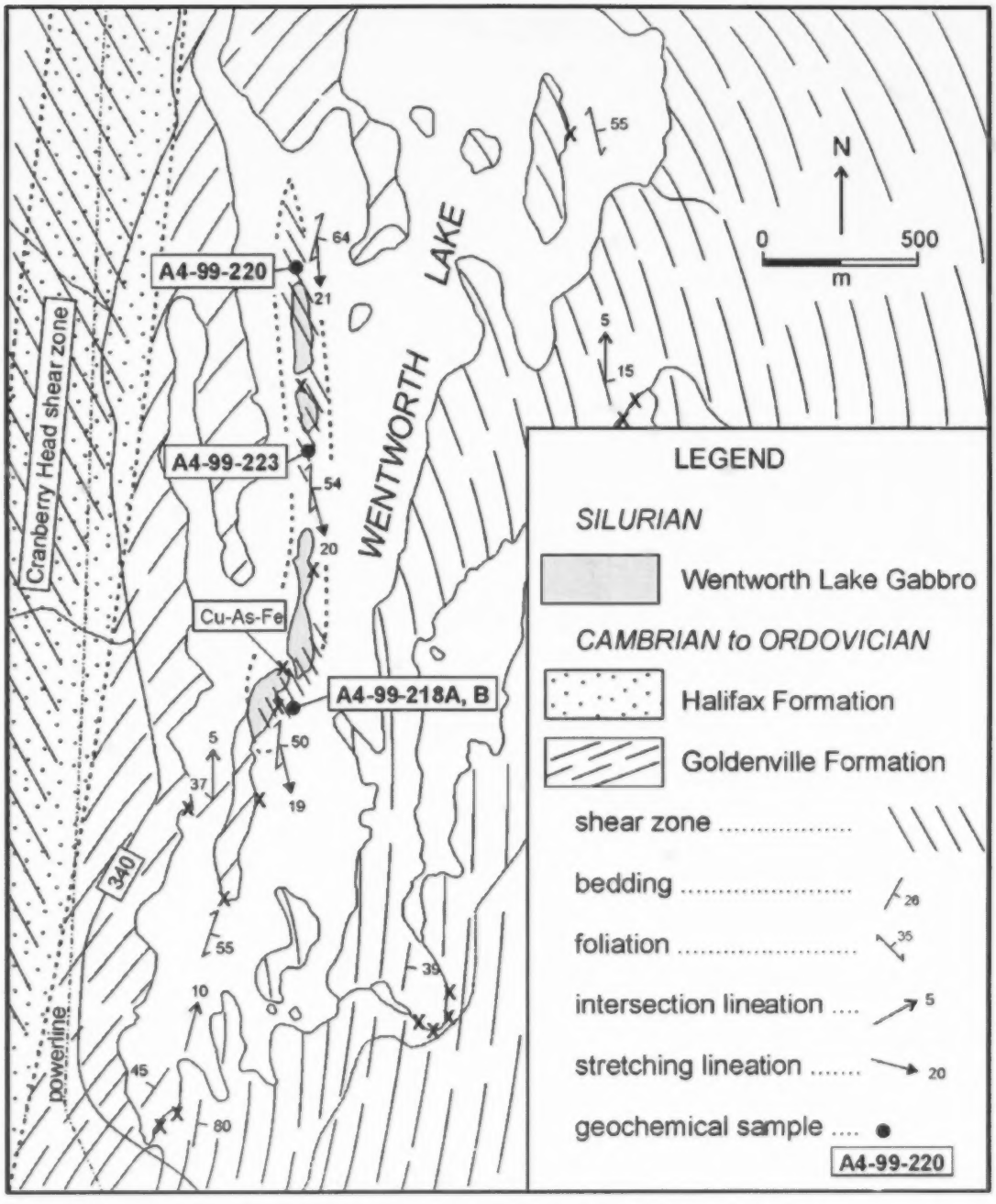

Figure 5. Simplified geology map of the Wentworth Lake area showing geochemical sample locations.

Based on thin section petrography in their host rocks, the amphibolite sheets have reached garnet-grade of metamorphism which has completely obliterated original igneous textures. This extensive recrystallization is in contrast to the relict igneous mineralogy and texture preserved in the gabbros, and suggests that the latter experienced a considerably lower grade of metamorphism, presumably greenschist facies or lower. Amphibole is the dominant mineral phase (63-77%) and forms subidioblastic, inclusion-rich grains that locally display uniform orientation that defines the foliation. In some samples elongate amphibole grains are at a high angle to the foliation and appear to have grown after deformation had ceased. Inclusions are typically flattened quartz, opaque minerals and titanite that define straight inclusion trails. Plagioclase (5-15%) is unaltered, subidioblastic to granoblastic and is of oligoclase composition. Quartz (3-16%) occurs as small intergranular or elongate grains with serrated to granoblastic margins, and is probably a product of metamorphism. Opaque minerals (< 7%) are small subhedral grains in the hornblende. Biotite is rare and occurs as interstitial grains. Epidote is common.

Chemical Characteristics

Chemical data are available for 39 samples from the gabbroic bodies (see Table 1, after references). The Mavillette Gabbro (Fig. 2) is represented by 25 analyses, of which 7 are from samples collected as part of this project, and 18 are samples from Calder (1981). The latter samples were re-analyzed for trace elements by X-ray fluorescence at the Regional Geochemical Centre, Saint Mary's University, to provide consistency with the trace element data sets from the other samples in this study. Nickersons Point Gabbro (Fig. 4) is represented by 5 samples and Wentworth Lake Gabbro (Fig. 5) by 4 samples. In addition, analyses were obtained from two samples from mafic sills in the vicinity of the Mavillette Gabbro (Fig. 2), and 3 samples were analyzed from amphibolite sheets in the White Rock Formation (Fig. 1).

Most of the analyzed samples have SiO_2 contents between about 45% and 52% (Table 1). Exceptions are 3 pegmatoid monzogabbro samples from the Mavillette Gabbro which contain a higher proportion of plagioclase relative to mafic minerals, and two leucocratic samples classified on the basis of mineralogy as monzonite by Calder (1981) that contain abundant K-feldspar as well as plagioclase. The three monzogabbro samples contain about 55-57% SiO_2 (Fig. 6a), whereas the two monzonite samples contain 62-63% SiO_2. The latter samples are not discussed further in this paper, which focuses on gabbroic rocks.

To illustrate and compare the overall chemical characteristics of the gabbroic samples, data are plotted against FeO^t/MgO ratio as an indication of degree of magma differentiation (Figs. 6, 7). Although the data are scattered, samples from the Mavillette Gabbro display trends of increasing SiO_2, Na_2O, and K_2O, and decreasing TiO_2, Fe_2O_3, MgO, and CaO with increasing FeO^t/MgO (Fig. 6). These trends are consistent with crystal fractionation processes involving the removal of mafic minerals and Ca-rich plagioclase. P_2O_5 shows a more complex pattern, with abundance initially increasing and then decreasing with increasing FeO^t/MgO (Fig. 6j), the decrease probably reflecting the initiation of apatite crystallization from the magma. Ni, Cr, and Pb contents are generally low, but Co, Cu, and Zn values are higher, up to 70, 40, and 160 ppm, respectively (Fig. 7). Ni, Cr, Co and Cu show a tendency to decrease with increasing FeO^t/MgO.

In comparison to Mavillette Gabbro, the other gabbroic units show different trends and patterns. They generally have lower FeO^t/MgO ratio, or higher SiO_2 in samples in which the FeO^t/MgO ratios overlap with those of the Mavillette Gabbro (Fig. 6). They generally have lower TiO_2, Fe_2O_3, Na_2O, and P_2O_5 and higher Al_2O_3 contents. However, these other gabbroic units show relatively wide variation in composition. The two sills are most similar to the compositions of the Mavillette Gabbro, and a link between those intrusions, as suggested by their geographic proximity and petrography, seems likely. The Nickersons Point and Wentworth Lake gabbros show general similarities, the most consistent difference being lower CaO in the Nickersons Point samples. The three amphibolite sheet samples generally overlap in composition with the

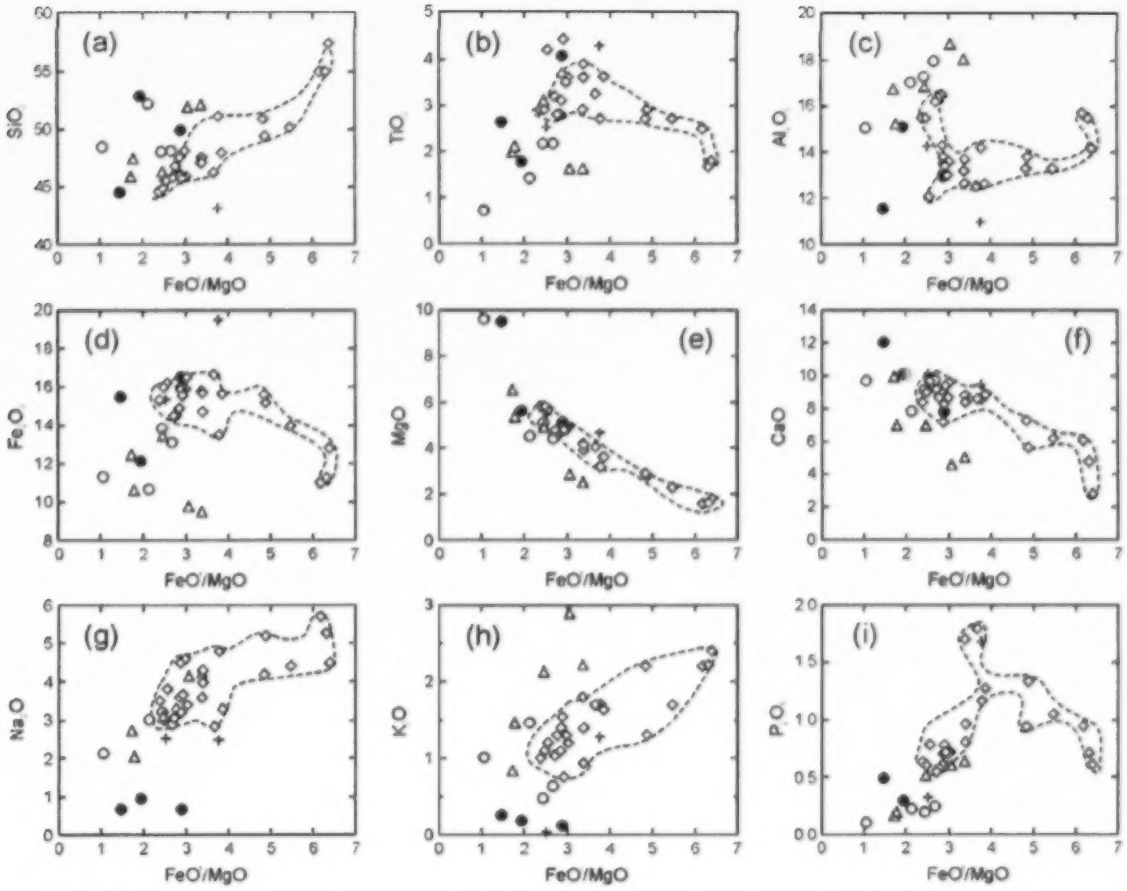

Figure 6. Major element oxides plotted against FeO^t/MgO to illustrate chemical characteristics of the gabbro bodies. Symbols as in Figure 3.

Nickersons Point and Wentworth Lake gabbro samples, but have lower Na_2O and K_2O contents, perhaps related to alteration. The amphibolite sample with lowest FeO^t/MgO ratio has over 150 ppm Ni, 400 ppm Cr, 81 ppm Co, 90 ppm Cu, and also relatively high Pb content. The sample from Wentworth Lake Gabbro with lowest FeO^t/MgO ratio also has elevated Ni and Cr values (Fig. 7).

With the exception of the four samples from Wentworth Lake Gabbro, all of the samples have trace element abundances and ratios consistent with alkalic affinity and origin in a within-plate tectonic setting. These interpretations are illustrated by plots of Zr/TiO_2 and Nb/Y ratios (Fig. 8a) and V and TiO_2 contents (Fig. 8b) on which most samples (except those from Wentworth Lake Gabbro) lie in the alkalic fields, and by plots of Zr/Y and Zr (Fig. 8c) and Ti-Zr-Y (Fig. 8d) on which most samples (including in these cases those from Wentworth Lake Gabbro) plot in the within-plate fields. A MORB-normalized multi-element variation diagram for the Mavillette Gabbro samples displays a pattern similar to that of average alkalic basalt, characterized by elevated Th, Nb, and P_2O_5 values (Fig. 9a). A similar plot for the two sills from the Mavillette area superimposed on the field for the Mavillette Gabbro samples (from Fig. 9a) displays their general similarity (Fig. 9b). The corresponding plot for the Nickersons Point Gabbro reflects the lower P_2O_5, Zr, and Y values.

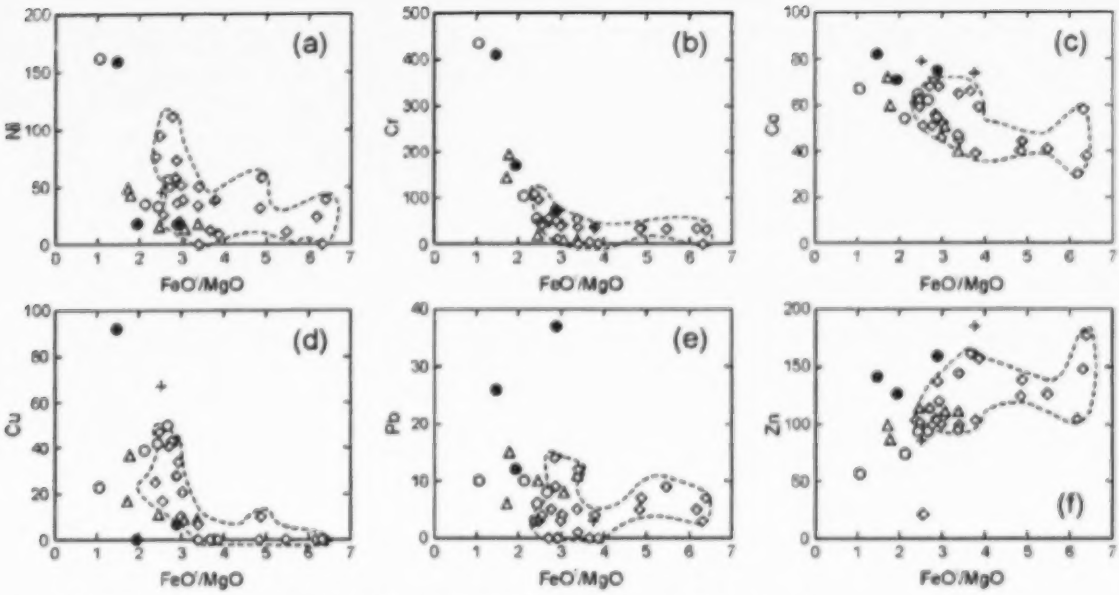

Figure 7. Plots of Ni, Cr, Co, Cu, Pb and Zn against FeO^t/MgO. Symbols as in Figure 3.

and appears less alkalic (Fig. 9c). Lower Th, Nb, P_2O_5, Zr, TiO_2, and Y are apparent in the Wentworth Lake Gabbro (Fig. 9d). The similarity of the amphibolite samples to the Nickersons Point Gabbro is apparent by comparing Figs. 9c and 9d.

Although detailed comparisons are difficult because of the wide scatter in the data, probably in large part the result of variable crystal fractionation processes combined with the effects of alteration and metamorphism, the chemical features of the gabbro bodies are generally similar to those of mafic rocks in the White Rock Formation in the Yarmouth area (MacDonald *et al.*, 2002). The latter rocks include amphibolite sheets and bodies, and amphibolite-facies metavolcanic rocks, both of which have within-plate alkalic compositions. The age of the metavolcanic rocks is well constrained to the Late Ordovician- Early Silurian by U-Pb dating of felsic tuff and the granitoid Brenton Pluton (Keppie and Krogh, 2000; MacDonald *et al.*, 2002). Based on their chemical similarities and geographic proximity, a similar age is inferred for the gabbroic rocks of this study.

Economic Geology

Numerous base metal and precious metal occurrences are know to be associated with the gabbro bodies (Figs. 2, 5) and are described in the Nova Scotia Department of Natural Resources Mineral Occurrence Database for NTS sheets 21A/04 and 21B/01. The Wentworth Lake Gabbro and associated country rocks were studied in detailed by O'Reilly (1978) who observed disseminated chalcopyrite, arsenopyrite, pyrite and magnetite in felsic pods associated with the mylonitic fabrics. Disseminated pyrrhotite ± magnetite occurs throughout the gabbro. He also observed that in the immediate area of the gabbro, calc-silicate nodules in metasandstone boulders contain significant pyrrhotite with lesser amounts of pyrite and chalcopyrite. O'Reilly (1978) concluded that the mineralization is spatially related to the intrusion and subsequent shearing.

Many of the mineral occurrences in the Cape St. Mary (Fig. 1) area appear to be spatially associated with gabbro sills and the carbonate and

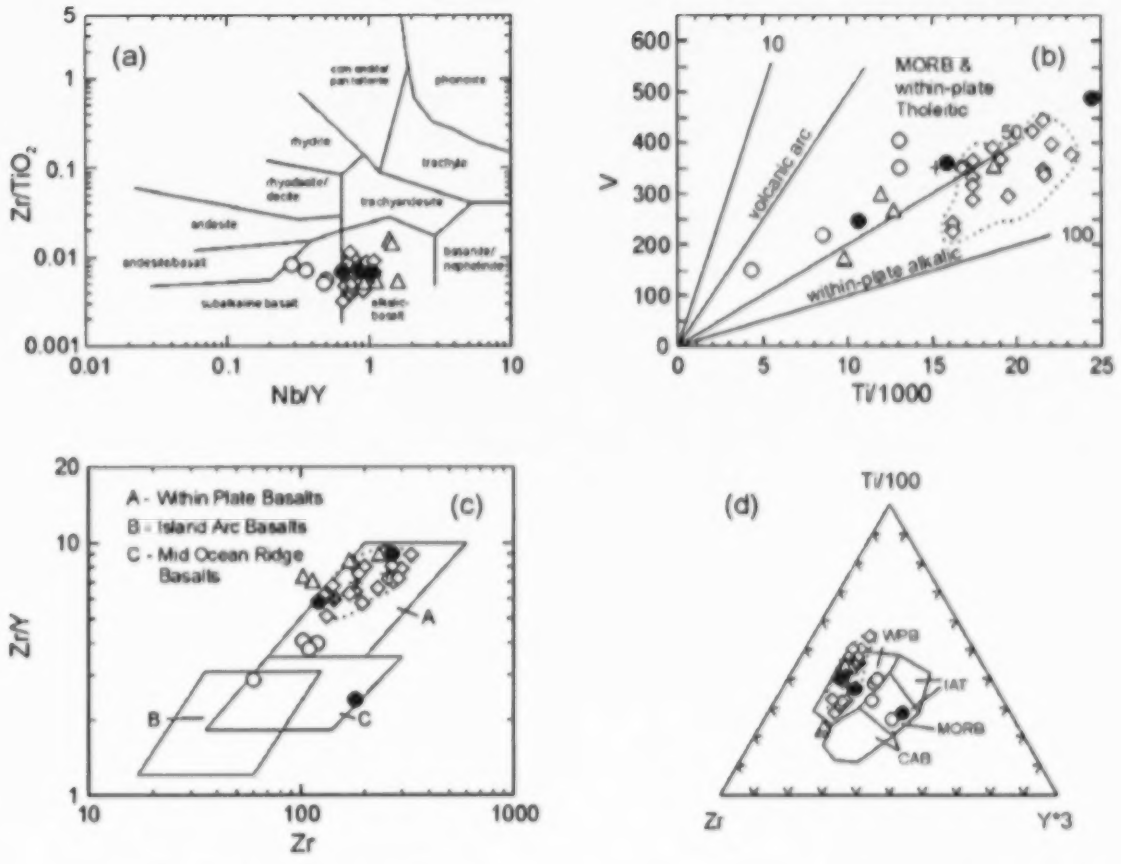

Figure 8. Chemical affinity and tectonic setting discrimination diagrams for mafic samples (less than 52% SiO_2). Labeled fields in (a) are from Winchester and Floyd (1977), (b) from Shervais (1982), (c) from Pearce and Norry (1979), and (d) from Pearce and Cann (1973). Abbreviations: MORB, mid-ocean ridge basalt; WPT, within-plate tholeiitic basalt; WPA, within-plate alkalic basalt; IAT, island arc tholeiite; CAB, calc-alkalic basalt; WPB, within-plate basalt. Symbols as in Figure 3.

or sericite alteration halos in the adjacent slate of the Halifax Formation. In these zones quartz veins locally contain varying amounts of galena, sphalerite, stibnite, arsenopyrite and chalcopyrite.

In addition to the base metal and precious metal occurrences, the Mavillette Gabbro has been quarried for "rip-rap" in the building of new wharfs and breakwaters in the area. Lately it has been investigated as a potential building stone/tile supply by the Nova Scotia Department of Natural Resources.

Conclusions

Although absolute ages are lacking from the gabbro bodies, the similarity of chemical features to those of mafic rocks in the White Rock Formation (MacDonald, 2000; MacDonald *et al.*, 2002) are consistent with a genetic relationship. If so, the gabbro bodies are probably Early Silurian, and have been deformed and metamorphosed together with the Goldenville, Halifax and White Rock formations during the Acadian Orogeny. This

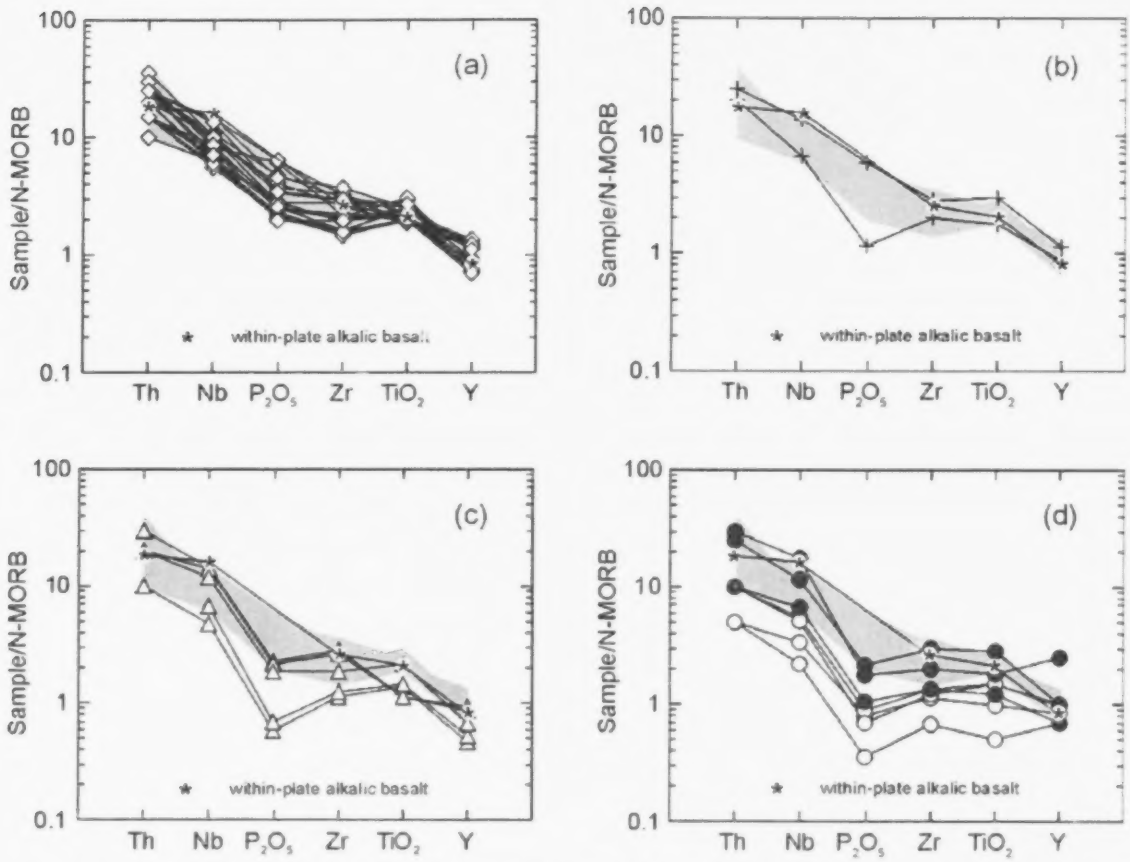

Figure 9. Multi-element variation diagrams for (a) Mavillette Gabbro, (b) mafic sills, (c) Nickersons Point Gabbro, and (d) Wentworth Lake Gabbro and amphibolite bodies. Field for samples from the Mavillette Gabbro in (a) is shown for comparison on (b), (c), and (d). MORB-normalizing values and data for average alkalic basalt are taken from Pearce (1996).

interpretation explains the apparent folded pattern of the Mavillette Gabbro, the boudinaged character of many of the sills and presence of foliation in some of the samples. In addition, the mineralogical "alteration" observed in many of the gabbroic samples may be due to low-grade regional metamorphism. This mafic intrusive and extrusive igneous activity would be consistent as a response to extension as the Meguma terrane rifted away from Gondwana.

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References

Calder, L. M. 1981: Geology of the Mavillette Intrusion, Digby County, Nova Scotia; BSc Honours thesis, Acadia University, Wolfville.

Calder, L. M. and Barr, S. M. 1982: Petrology of the Mavillette Intrusion Digby County, Nova Scotia; Maritime Sediments and Atlantic Geology, v. 18, p. 29-40.

Faribault, E. R. 1920: Investigations in southwestern Nova Scotia; *in* Summary Report, 1919; Canada Department of Mines, Geological Survey, Part F, p. 2F-20F.

Ham, L. J. and MacDonald, M. A. 1994: Geological map of Wentworth Lake, (NTS. Sheet 21A/04 and part of 20P/13), South Mountain Batholith Project; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Map 94-03, scale 1:50 000.

Keppie, J. D. and Krogh, T. E. 2000: 440 Ma igneous activity in the Meguma Terrane, Nova Scotia, Canada: part of the Appalachian overstep sequence; American Journal of Science, v. 300, p. 528-538.

MacDonald, L. A. 2000: Petrology and stratigraphy of the White Rock Formation, Yarmouth area, Nova Scotia; MSc thesis, Acadia University, Wolfville, Nova Scotia.

MacDonald, L. M., Barr, S. M., White, C. E. and Ketchum, J. W. F. 2002: Petrology, age, and tectonic setting of the White Rock Formation, Meguma terrane, Nova Scotia: evidence for Silurian continental rifting; Canadian Journal of Earth Sciences, v. 39, p. 259-277.

O'Reilly, G. A. 1978: Copper mineralization at Wentworth Lake, Digby County, southwestern Nova Scotia; *in* Mineral Resources Division, Report of Activities, 1977; ed. D. J. Gregory; Nova Scotia Department of Mines, Report 78-1, p. 67-75.

Pearce, J. A. 1996: A user=s guide to basalt discrimination diagrams; *in* Trace element geochemistry of volcanic rocks: applications for massive sulphide exploration; ed. D. A. Wyman; Geological Association of Canada, Short Course Notes, v. 12, p. 79-113.

Pearce, J. A. and Cann, J. R. 1973: Tectonic setting of basic volcanic rocks determined using trace element analysis; Earth and Planetary Science Letters, v. 19, p. 290-300.

Pearce, J. A. and Norry, M. J. 1979: Petrogenetic implications of Ti, Zr, Y, and Nb variations in volcanic rocks; Contributions to Mineralogy and Petrology, v. 69, p. 33-47.

Shervais, J. W. 1982: Ti-V plots and the petrogenesis of modern and ophiolite lavas; Earth and Planetary Science Letters, v. 59, p. 101-118.

Slauenwhite, D.1999: Regional Geochemical Centre. Website http://www.stmarys.ca/academic/science/geology/geochemctr/brochure.html

Smitheringale, W. G. 1973: Geology of part of Digby, Bridgetown, and Gaspereau map areas, Nova Scotia; Geological Survey of Canada Memoir 375.

Streckeisen, A. 1977: To each plutonic rock its proper name; Earth Science Reviews, v. 12, p. 1-33.

Taylor, F. C. 1967: Reconnaissance Geology of Shelburne map-area, Queens, Shelburne, and Yarmouth Counties, Nova Scotia; Geological Survey of Canada Memoir 349.

Taylor, F. C. 1969: Geology of the Annapolis-St. Mary's Bay area, Nova Scotia; Geological Survey of Canada Memoir 358.

White, C. E., Horne, R. J., Ténière, P. J. Jodrey, M. J. and King, M. S. 2001: Geology of the Meteghan River-Yarmouth area: a progress report on the Southwest Nova Scotia Mapping Project; *in* Nova Scotia Department of Natural Resources, Minerals and Energy Branch, Report of Activities 2000; ed. D. R. MacDonald; Report ME 2001, p. 95-111.

Winchester, J. A. and Floyd, P. A. 1977: Geochemical discrimination of different magma series and their differentiation products using immobile elements; Chemical Geology, v. 20, p. 325-343.

Table 1. Geochemical data from gabbroic rocks in southern Nova Scotia.

Sample	SiO_2	TiO_2	Al_2	Fe_2	MnO	MgO	CaO	Na_2	K_2	P_2	LOI	Total
Mavillette Gabbro												
LMC-1	45.88	3.61	13.58	16.45	0.25	4.87	9.58	3.36	1.18	0.72	1.32	100.80
LMC-2	49.41	2.91	15.78	15.19	0.25	2.82	5.58	5.24	1.29	1.33	2.30	102.10
LMC-3	50.85	2.71	13.34	15.57	0.27	2.87	7.25	4.21	2.17	0.94	1.08	101.26
LMC-4	54.95	2.53	15.73	11.00	0.22	1.59	6.13	5.70	2.20	0.95	1.36	102.36
LMC-5	51.14	2.70	14.17	13.53	0.25	3.15	8.58	4.83	1.65	1.16	1.34	102.50
LMC-6	44.61	2.87	15.46	15.26	0.21	5.84	8.43	3.51	1.03	0.63	2.18	100.03
LMC-7	45.48	4.20	12.12	16.20	0.23	5.70	9.66	3.82	1.19	0.78	1.36	100.74
LMC-8	63.10	0.74	17.66	3.35	0.06	0.44	0.94	7.77	4.24	0.12	1.00	99.42
LMC-9a	61.97	0.74	17.62	3.28	0.06	0.39	0.98	7.63	4.30	0.12	0.84	97.93
LMC-10	48.07	3.52	12.96	15.53	0.23	4.79	8.66	4.59	1.28	0.70	0.98	101.31
LMC-11	46.23	2.81	16.46	14.89	0.19	4.72	9.09	3.60	1.07	0.61	1.72	101.39
LMC-12	47.45	3.64	13.72	14.72	0.25	3.94	8.80	4.30	1.40	0.80	1.28	100.30
LMC-13	57.44	1.81	14.19	12.81	0.24	1.81	2.81	4.45	2.37	0.61	1.86	100.40
LMC-14	50.14	2.68	13.27	14.00	0.25	2.25	6.17	4.35	1.65	1.05	5.42	101.23
LMC-15	44.91	2.91	15.47	15.95	0.21	5.80	8.97	2.98	1.06	0.60	2.10	100.96
LMC-17	46.82	2.75	16.43	14.49	0.19	4.72	8.74	3.27	1.33	0.58	2.26	101.58
LMC-18	47.45	3.09	14.32	15.96	0.24	5.02	7.16	4.45	1.41	0.70	1.70	101.50
LMC-19	47.09	2.93	13.19	15.82	0.25	4.24	8.83	3.58	1.83	1.70	1.32	100.78
MV01-1	46.01	3.68	13.82	15.85	0.22	4.94	8.27	3.21	1.54	0.78	1.56	99.87
MV01-2	46.22	3.25	12.50	16.65	0.28	4.07	8.60	2.85	1.70	1.80	1.71	99.62
MV01-4A	45.77	4.42	13.40	15.56	0.20	4.79	9.38	3.66	0.75	0.72	1.68	100.33
MV01-5	45.80	3.19	16.21	14.48	0.19	4.78	9.20	3.06	1.03	0.55	1.90	100.38
MV01-6A	47.98	3.62	12.61	15.64	0.26	3.63	8.82	3.30	1.63	1.27	1.70	100.45
MV01-6B	54.99	1.66	15.48	11.29	0.22	1.61	4.76	5.26	2.21	0.71	1.88	100.07
MV01-7	47.09	3.88	12.66	15.71	0.26	4.15	8.36	3.98	0.94	0.96	1.59	99.58
Mavillette sills												
B01-RJH-331	45.65	2.54	14.25	15.37	0.22	5.47	10.14	2.52	0.03	0.33	2.77	99.28
B01-RJH-408	43.19	4.27	10.97	19.48	0.32	4.65	9.44	2.47	1.28	1.68	1.66	99.41
Nickersons Point Gabbro												
NP01-2B	45.91	1.99	16.73	12.48	0.15	6.51	9.93	2.73	0.84	0.16	2.30	99.73
NP01-3	51.93	1.63	18.71	9.76	0.18	2.87	4.58	4.14	2.89	0.61	2.46	99.75
NP01-5	47.49	2.12	15.25	10.62	0.15	5.39	6.96	2.04	1.46	0.20	9.49	101.16
NP01-6	46.33	3.11	16.84	13.46	0.29	4.92	6.98	3.10	2.13	0.52	1.89	99.57
016-W00-276	52.10	1.63	18.01	9.50	0.15	2.53	5.01	4.23	2.21	0.64	2.79	98.83

Table 1. continued

Sample	SiO_2	TiO_2	Al_2	Fe_2	MnO	MgO	CaO	Na_2	K_2	P_2	LOI	Total
Wentworth Lake Gabbro												
A4-99-218A	48.45	0.72	15.06	11.31	0.15	9.62	9.67	2.13	1.01	0.10	1.32	99.54
A4-99-218B	52.18	1.42	17.02	10.69	0.14	4.53	7.82	3.01	1.46	0.22	1.23	99.73
A4-99-220	48.10	2.17	17.95	13.14	0.16	4.40	9.72	2.91	0.64	0.25	1.44	100.88
A4-99-223	48.00	2.18	17.29	13.86	0.18	5.10	9.12	3.21	0.48	0.19	0.59	100.20
Amphibolite sills												
A4-W01-111B	49.90	4.08	12.93	16.51	0.27	5.13	7.80	0.68	0.12	0.60	1.53	99.54
A4-W01-206C	52.83	1.78	15.10	12.12	0.19	5.64	10.08	0.95	0.18	0.30	0.90	100.06
A4-W01-208B	44.51	2.64	11.55	15.48	0.25	9.49	12.03	0.66	0.26	0.49	2.43	99.79

Sample	Ba	Rb	Sr	Y	Zr	Nb	Th	Pb	Ga	Zn	Cu	Ni	V	Cr	Co	U	La	Nd
Mavillette Gabbro																		
LMC-1	nd	22	455	24	143	18	5	4	nd	106	21	39	444	42	52	<1	22	27
LMC-2	nd	25	441	39	273	29	5	7	nd	138	10	58	289	34	44	<1	55	56
LMC-3	nd	30	350	36	259	28	7	5	nd	124	<4	32	228	33	40	<1	50	60
LMC-4	nd	25	524	41	332	29	5	5	nd	104	<4	24	206	34	30	<1	53	62
LMC-5	423	24	460	35	231	25	5	4	nd	103	<4	39	243	32	39	<1	41	54
LMC-6	445	18	500	23	141	17	2	3	nd	103	25	76	333	109	61	<1	30	35
LMC-7	380	19	259	26	133	17	4	4	nd	21	17	26	457	42	51	<1	21	32
LMC-8	1292	29	318	55	704	28	8	8	nd	74	6	0	51	33	10	4	60	52
LMC-9a	1375	30	323	54	698	26	8	7	nd	45	6	0	51	35	11	4	60	47
LMC-10	505	18	367	28	180	20	5	3	nd	100	10	52	423	38	46	<1	27	42
LMC-11	342	18	466	22	135	15	3	14	nd	104	43	58	355	68	56	<1	25	29
LMC-12	410	22	387	27	170	21	3	12	nd	99	7	50	347	37	45	<1	26	40
LMC-13	802	31	526	49	437	34	5	7	nd	177	<4	39	156	31	38	<1	68	37
LMC-14	605	23	480	38	298	28	4	9	nd	126	<4	11	227	32	41	<1	48	60
LMC-15	315	18	456	21	130	16	4	3	nd	101	47	95	365	97	59	<1	21	27
LMC-17	384	22	556	21	142	16	3	5	nd	99	43	111	353	61	51	<1	23	32
LMC-18	1955	21	681	25	200	20	5	9	nd	103	28	73	392	75	55	<1	27	50
LMC-19	502	26	397	34	196	22	6	5	nd	95	<4	34	318	54	47	1	38	53
MV01-1	991	24	702	27	247	27	5	<3	27	137	28	36	399	50	69	<1	29	39
MV01-2	152	25	459	40	289	39	5	<3	25	161	<4	12	297	4	66	<1	43	55
MV01-4A	<20	15	394	25	189	23	3	<3	25	120	34	20	485	11	68	<1	22	31
MV01-5	30	16	560	21	174	19	3	<3	25	113	41	50	368	56	68	<1	16	21
MV01-6A	246	21	438	37	331	40	4	<3	28	157	<4	9	337	<4	59	<1	44	46
MV01-6B	762	27	593	43	365	41	5	3	31	148	<4	<3	135	<4	58	<1	51	58
MV01-7	71	13	377	33	268	36	5	1	27	144	<4	<3	378	<4	65	<1	36	41

Table 1. continued

Sample	Ba	Rb	Sr	Y	Zr	Nb	Th	Pb	Ga	Zn	Cu	Ni	V	Cr	Co	U	La	Nd
Mavillette sills																		
B01-RJH-331	<20	6	395	26	180	18	4	3	23	85	67	45	351	53	79	<1	15	18
B01-RJH-408	<20	23	434	34	257	37	5	3	21	185	<4	37	397	35	74	<1	38	45
Nickersons Point Gabbro																		
NP01-2B	<20	22	490	14	103	13	2	6	22	99	17	49	300	144	72	<1	11	14
NP01-3	954	99	615	26	235	38	4	8	28	111	9	14	174	9	51	<1	37	36
NP01-5	98	35	299	16	113	18	<2	15	21	87	37	43	269	194	60	1	18	16
NP01-6	644	74	586	20	169	32	4	10	24	114	11	15	357	20	63	<1	23	26
016-W00-276	483	58	574	28	258	39	6	11	27	111	9	18	173	10	40	1	37	42
Wentworth Lake Gabbro																		
A4-99-218A	158	23	414	21	60	6	0	10	17	57	23	162	149	436	67	<1	6	8
A4-99-218B	139	48	549	25	102	9	0	10	20	74	39	35	219	104	54	<1	5	21
A4-99-220	317	12	541	30	120	15	2	8	24	93	50	56	353	49	62	1	10	15
A4-99-223	81	6	578	29	110	14	2	6	24	93	42	33	406	56	65	1	19	24
Amphibolite sills																		
A4-W01-111B	<25	7	115	30	271	31	5	37	24	159	7	17	490	72	75	<1	33	33
A4-W01-206C	84	8	208	21	122	18	2	12	22	126	<4	18	248	171	71	2	18	19
A4-W01-208B	<25	10	60	75	180	48	6	26	15	141	92	159	362	410	82	1	36	32

[1]Footnote: Most analyses were done by X-ray Fluorescence at the Regional Geochemical Centre, Saint Mary's University, Halifax, Nova Scotia, using methods described by Slauenwhite (1999).
Exceptions are the LMC samples for which major element oxide data are from Calder (1981).
Analytical error is generally less than 5% for major elements and 2-10% for trace elements. Fe_2O_{3t} is total Fe as Fe_2O_3, LOI is loss on ignition at 1000°C, nd = not determined.

New Age Controls on Rock Units in pre-Carboniferous Basement Blocks in Southwestern Cape Breton Island and Adjacent Mainland Nova Scotia[1]

C. E. White, S. M. Barr[2] and J. W. F Ketchum[3]

Introduction

Pre-Carboniferous rocks are exposed in five areas in southwestern Cape Breton Island and adjacent mainland Nova Scotia: Creignish Hills, North Mountain, Sporting Mountain, Cape Porcupine, and Isle Madame (Fig. 1). Bedrock mapping in these areas was conducted at times through the 1980s and 1990s as part of the Canada-Nova Scotia Mineral Development and Cooperative agreements and various other university-based research projects. The Targeted Geoscience Initiative (TGI) project in south-central Cape Breton Island (2000-2003) provided an opportunity to compile and re-assess these data, as well as to acquire new data that are critical in interpreting and understanding the complex pre-Carboniferous geology in the area. In addition to their regional geologic significance, the pre-Carboniferous rocks have importance as hosts for base- and precious-metal deposits and as sources of building stone and aggregate. In addition, relations between these "basement blocks" were important in localizing subsequent basin development (King, 2002) and, hence, influenced the distribution and thickness of Carboniferous and younger sedimentary units.

One of the most important unresolved questions in these areas of pre-Carboniferous rocks is the age of the igneous and metamorphic units that constitute them. Hence, a program of U-Pb geochronology was undertaken at the Royal Ontario Museum, Toronto, in part funded through TGI. The purpose of this paper is to present preliminary results of this work.

Geological Setting

The boundary between the Mira (Avalon) and Bras d'Or terranes of Cape Breton Island (e.g. Barr and Raeside, 1989) has been placed through the Bras d'Or Lakes (Fig. 1) such that the North Mountain and Creignish Hills are part of the Bras d'Or terrane, whereas the Sporting Mountain and Isle Madame areas are in the Mira terrane. The location of the boundary was investigated by King (2002), who confirmed its position and better defined its shape on the basis of geophysical modeling.

The position of the Mira-Bras d'Or terrane boundary southwest of the Strait of Canso is uncertain. Barr *et al.* (1998) showed it offset 200 km to the north, in a dextral sense, along a postulated "Canso fault", inferred to follow the western margin of the Creignish Hills (Fig. 1). The orientation of this pre-Carboniferous fault is inferred from mylonitic rocks in the Cape Porcupine Complex (White *et al.*, 2001), located on the western side of the Strait of Canso (Fig. 1), opposite the inferred termination of the Mira - Bras d'Or terrane boundary (King, 2002). However, the Canso fault is not recognized in some other regional interpretations in which rock units and structural features are extended across the Strait of Canso with little or no disruption (e.g. Keppie *et al.*, 1998). It should be noted that the Canso fault is a pre-Carboniferous structure, and not the same as the younger, northwesterly trending Strait of Canso fault which offsets Carboniferous units (Fig. 1).

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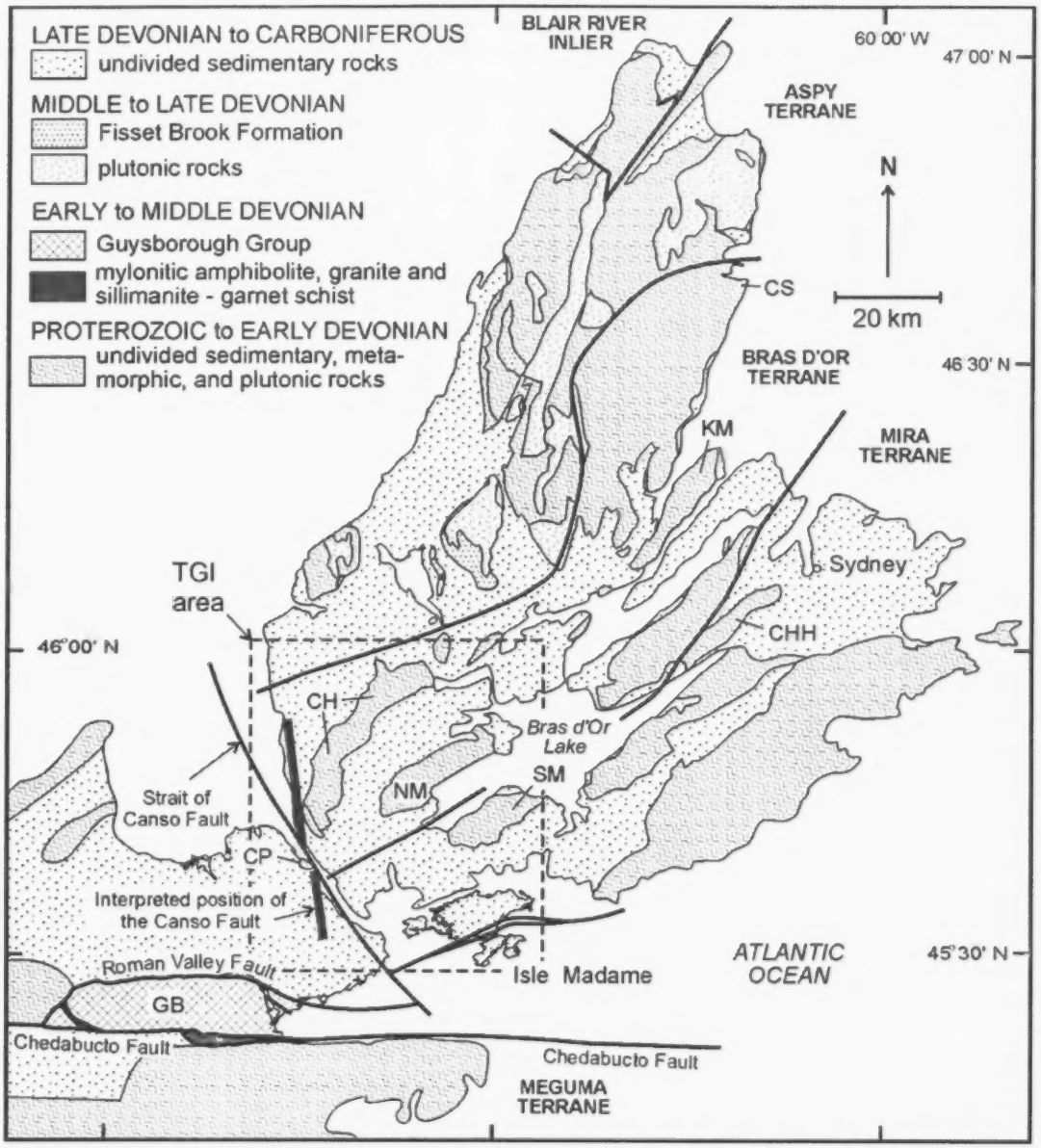

Figure 1. Simplified geological map of Cape Breton Island and adjacent northern mainland Nova Scotia showing the distribution of pre-Carboniferous units. The Targeted Geoscience Initiative (TGI) study area is indicated by the box. Terranes and terrane boundaries are after Barr *et al.* (1998). Abbreviations: CH, Creignish Hills; CHH, Coxheath Hills; CP, Cape Porcupine; CS, Cape Smoky; GB, Guysborough block; KM, Kellys Mountain; NM, North Mountain; SM, Sporting Mountain.

The study area may also contain the boundary between the Mira and Meguma terranes to the south. Earlier reconstructions assumed that the Mira-Meguma terrane boundary followed the inferred offshore extension of the Chedabucto Fault into the Orpheus Graben Fault along the northern margin of the Orpheus Graben (Marillier *et al.*, 1989; Jansa *et al.*, 1993). However, Webster *et al.*

(1998) recognized that a branch of the Chedabucto Fault (Roman Valley Fault; Fig. 1) may follow the northern margin of the Guysborough block. This interpretation provides support for an earlier suggestion (Barr *et al.*, 1992), based on basement exposures in the Isle Madame area, that the terrane boundary may follow splays of this fault system into southern Cape Breton Island (Fig. 1). Hence, metamorphic and igneous units in the Isle Madame area could be related to the Meguma terrane, rather than Mira terrane as more generally assumed.

Dating Methods

Samples were processed at the ROM using a jaw crusher for initial crushing, a disk mill for sample reduction to sand-sized particles, and a Wilfley table, heavy liquids (bromoform and methylene iodide) and a Frantz magnetic separator for isolation of heavy mineral fractions. Zircon was selected from the least paramagnetic fraction by hand picking under a binocular microscope. All picked zircon grains were given an air abrasion treatment to eliminate cracked grains and remove exterior surfaces (Krogh, 1982). Final selection of grains for analysis was then made. The weight of each fraction (typically one or two grains) was either estimated or measured using a microbalance. As the weights are normally small (generally <3 micrograms), both the measured and estimated weights are accurate only to about ±50%. However, this only affects the calculation of Pb and U concentrations and has no influence on age data.

The selected grains were washed in 4N and then 7N HNO_3 and then loaded into Teflon bombs with HF and a measured amount of ^{205}Pb - ^{235}U isotopic tracer solution (Krogh, 1973). Dissolution occurred over four to five days at 195°C. No chemical isolation of U and Pb was carried out on the dissolved grains.

Fractions were dried with phosphoric acid and then loaded with silica gel on outgassed rhenium filaments. The isotopic compositions of Pb and U were measured using a single Daly collector with a pulse counting detector in a solid source VG354 mass spectrometer. A detector mass discrimination of 0.14% per atomic mass unit (AMU) and a deadtime of 22.5 nanoseconds were employed for Daly detector measurements. A thermal source mass discrimination correction of 0.1% per atomic mass unit for both Pb and U was also used.

The assigned laboratory blank for U is 0.2 pg. Total measured common Pb in samples was below 1 pg in nearly all cases and was assigned the isotopic composition of the lab blank. Error estimates were calculated by propagating known sources of analytical uncertainty for each analysis, including ratio variability (within run), uncertainty in the fractionation correction, and uncertainties in the isotopic composition of the laboratory blank. Decay constants used are those of Jaffey *et al.* (1971). All uncertainties in the text below and on concordia diagrams (Fig. 2) are given at the 95% confidence level. Discordia lines and concordia intercept ages were calculated by the method of Davis (1982) using the in-house program ROMAGE. Average $^{207}Pb/^{206}Pb$ ages or $^{206}Pb/^{238}U$ ages were also calculated using ROMAGE. Probability of fit measures the scatter of analyses with respect to a Pb-loss line. A value of around 50% would be expected for unimodal data sets with correctly chosen analytical errors. Low probability of fit suggests real differences in Pb loss history and/or zircon crystallization age.

Concordia diagrams for the zircon analyses are presented in Figure . Data tables for the analyses will be published elsewhere.

Creignish Hills and North Mountain Areas

Geological Summary

Rock units are similar in the Creignish Hills and North Mountain areas (Fig. 3). Campbell (1990) divided metamorphic rocks in the Creignish Hills area into the Blues Brook Formation (mainly low-grade rocks including slate, quartzite, marble, and metavolcanic rocks) and the Skye Mountain metamorphic suite (mainly higher grade rocks that include low-pressure/high- temperature amphibolite-facies gneiss and migmatite). Our preliminary work in the area during 2002 generally supported this subdivision, although some unresolved problems in the assignment of rocks to

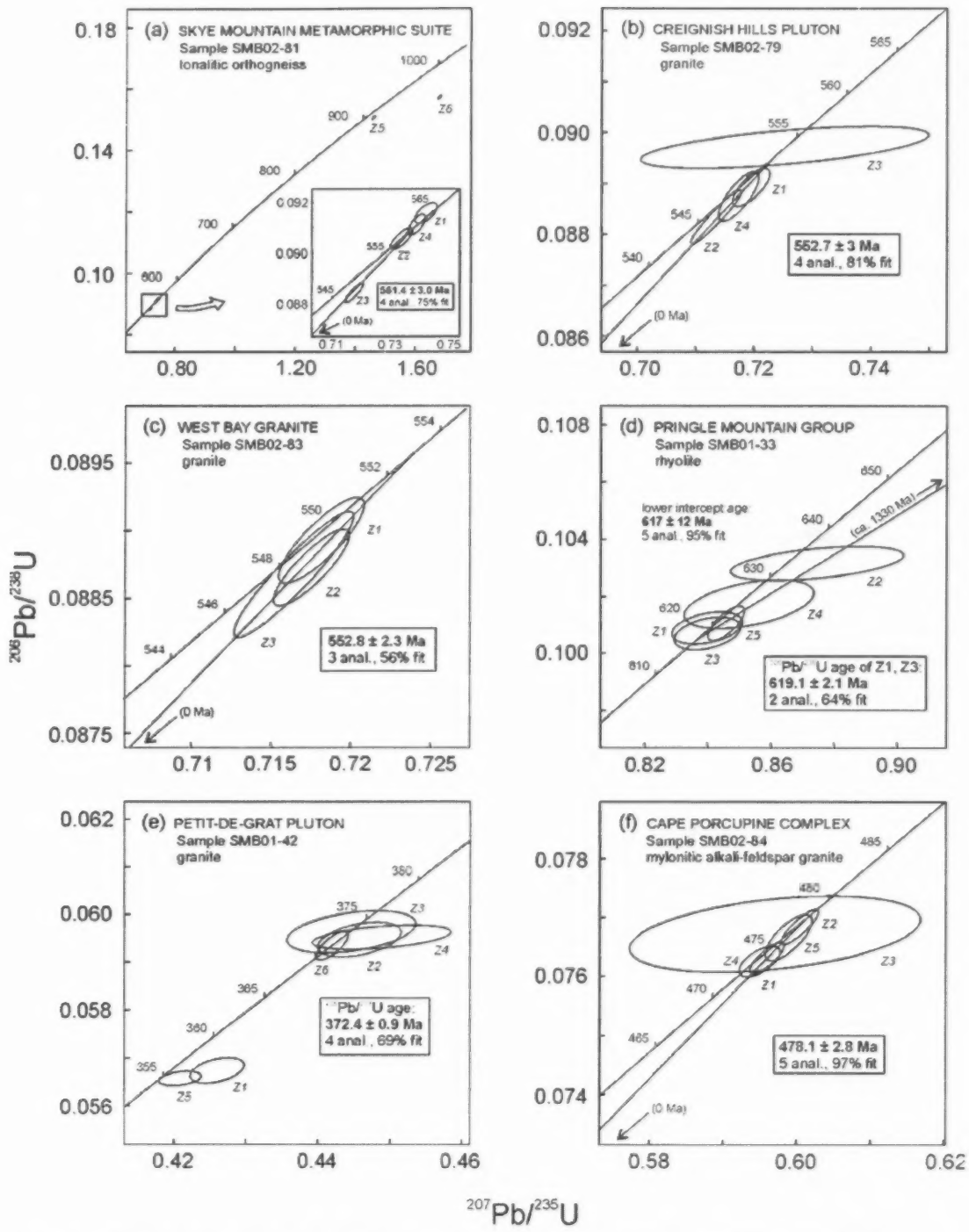

Figure 2. U-Pb concordia diagrams for samples described in the text. The data table for these diagrams will be published elsewhere.

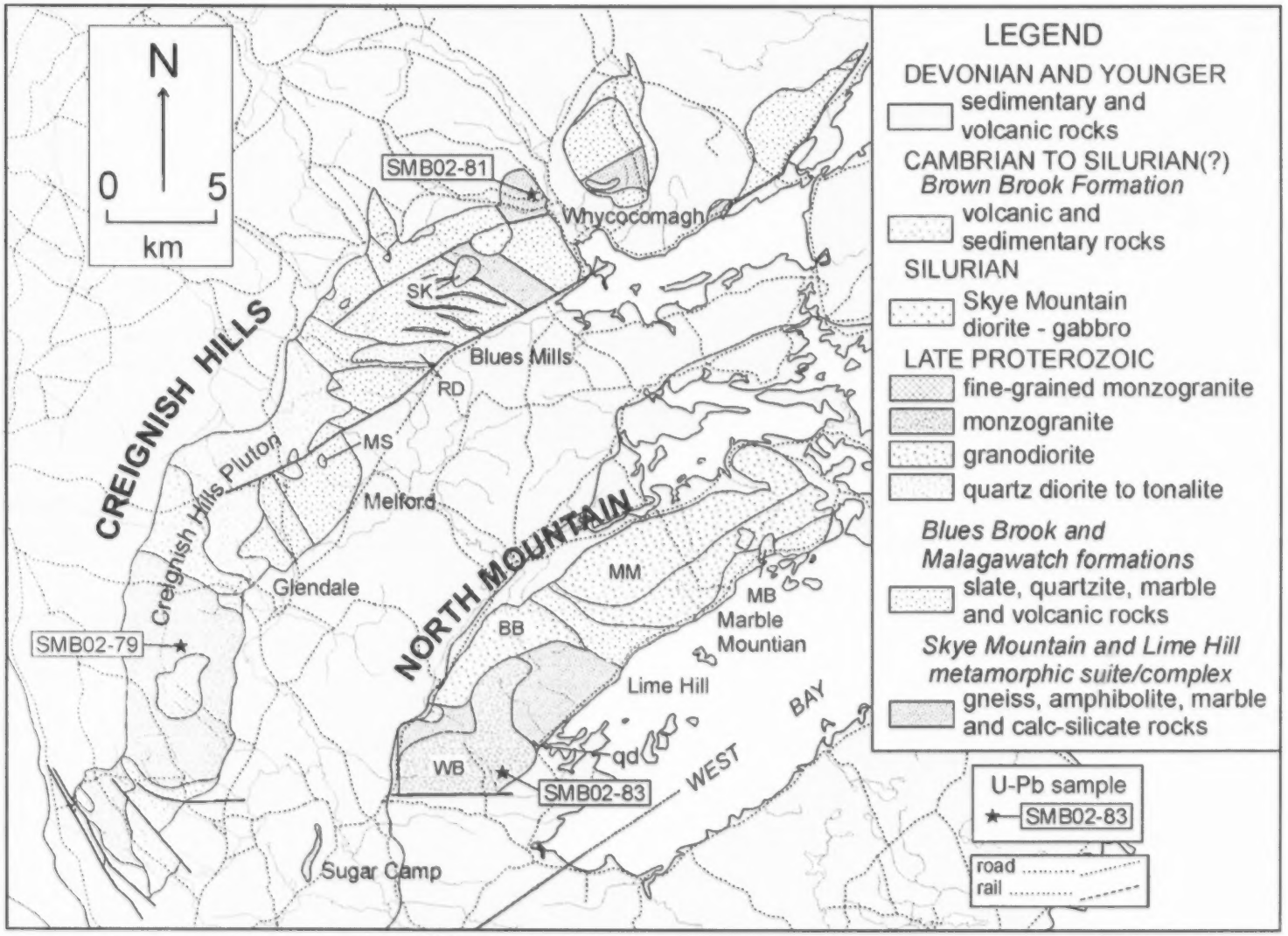

Figure 3. Simplified geological map of the Creignish Hills and North Mountain areas, compiled from various sources including White *et al.* (1990), Campbell (1990), and Justino (1991). Locations for dated samples SMB02-79, 81, and 83 are indicated. Abbreviations: BB, Big Brook Pluton; MB, Mill Brook quartz diorite; MM, Marble Mountain Pluton; MS, Melford stock; qd, unnamed quartz diorite; RD, River Denys Pluton; SK, Skye Mountain granite; WB, West Bay Granite.

these units showed the need for additional field work, planned for 2003. The corresponding units in the North Mountain area are the Malagawatch Formation and Lime Hill gneissic complex, as mapped by Justino (1991). In both areas, all of these metamorphic rocks were previously assigned to the George River Series or Group (Milligan, 1970); however, in current terminology, the Blues Brook and Malagawatch formations are part of the George River Metamorphic Suite, whereas the Skye Mountain and Lime Hill units are part of the Bras d'Or Gneiss (Keppie, 2000).

The metamorphic units in both areas have been intruded by varied dioritic to granitic plutons (e.g. White *et al.*, 1990; Justino and Barr, 1994). In the Creignish Hills, most of the plutonic rocks have been assigned to the Creignish Hills Pluton (White *et al.*, 1990; Campbell, 1990), and in the North Mountain area three main suites have been defined: Marble Mountain, Big Brook, and West Bay (Justino, 1991; Justino and Barr, 1994). The Creignish Hills Pluton is mainly granitic in the south and dioritic in its northwestern part, with outlying plutons of both dioritic (e.g. River Denys Pluton) and granitic (e.g. Skye Mountain granite; Melford Stock) composition (White *et al.*, 1990; Campbell, 1990; Keppie *et al.*, 2000). In the North Mountain area, the Big Brook and Marble Mountain plutons are mainly of granodiorite composition, although small tonalitic to dioritic bodies (e.g. Mill Brook quartz diorite) occur along their margins. The West Bay Pluton is mainly coarse-grained monzogranite that likely extends south of the Marble Mountain block under Carboniferous cover, based on the presence of outcrops of similar granite in the Sugar Camp gypsum quarry (Fig. 2). A small area of quartz diorite occurs on the eastern margin of the West Bay granite.

Prior to the present study, crystallization ages of plutons in the Creignish Hills were constrained by U-Pb (zircon) ages of 586 ±- 2 Ma and 540 ± 3 Ma from the Melford Stock and River Denys Pluton, respectively (Keppie *et al.*, 1998a). Zircon from the dioritic part of the Creignish Hills Pluton yielded a U-Pb age of 553 ± 2 Ma, slightly older than $^{40}Ar/^{39}Ar$ (hornblende) cooling ages of ca. 550-535 Ma from the dioritic units (Dallmeyer and Keppie, 1993; Keppie *et al.*, 1990, 1998a, 2000). The granitic part of the Creignish Hills Pluton, which underlies about half of the area, had not been dated by the U-Pb method, and earlier Rb-Sr results were uncertain and ambiguous (White *et al.*, 1990). An age of ca. 495 Ma was postulated based on petrological similarity to the Kellys Mountain and Cape Smoky plutons farther to the east and northeast in the Bras d'Or terrane (White *et al.*, 1990). A small mafic pluton in the eastern Creignish Hills (Skye Mountain gabbro-diorite) has yielded a much younger U-Pb (zircon) age of 439 ± Ma (Keppie *et al.*, 1998b, 2000).

In the North Mountain area, pluton crystallization ages are more poorly constrained than in the Creignish Hills (Fig. 4). An anatectic granite sheet in the Lime Hill gneissic complex yielded a concordant U-Pb (monazite) age of 553 ± 3 Ma (Keppie *et al.*, 1998a), similar to U-Pb (zircon) ages of 545 ± 7 Ma and 540 ± 1 Ma from tonalitic orthogneiss and a granitic dyke in the gneiss (Sangster *et al.*, 1990). Hornblende from the Marble Mountain granodiorite, Mill Brook quartz diorite, and an unnamed quartz diorite body adjacent to the West Bay Granite yielded $^{40}Ar/^{39}Ar$ cooling ages of ca. 555-545 Ma (Keppie *et al.*, 1990).

The minimum ages of metamorphic units in both the Creignish Hills and North Mountain areas are constrained by the ages of plutons that intruded them. Their maximum ages are estimated from ca. 640 Ma detrital zircon ages in the metasedimentary units, although most detrital grains are much older, ranging back to the Archean (Keppie *et al.*, 1997; Barr *et al.*, submitted).

New U-Pb (Zircon) Ages

Samples for dating were collected from an orthogneissic component in the Skye Mountain metamorphic suite, granite in the Creignish Hills Pluton, and the West Bay Granite.

Dated sample SMB02-81 from the Skye Mountain metamorphic suite was collected from an active quarry north of Skye Mountain (Fig. 2; UTM coordinates 5094125N, 642350E). It is a fine- to medium-grained tonalitic orthogneiss that consists

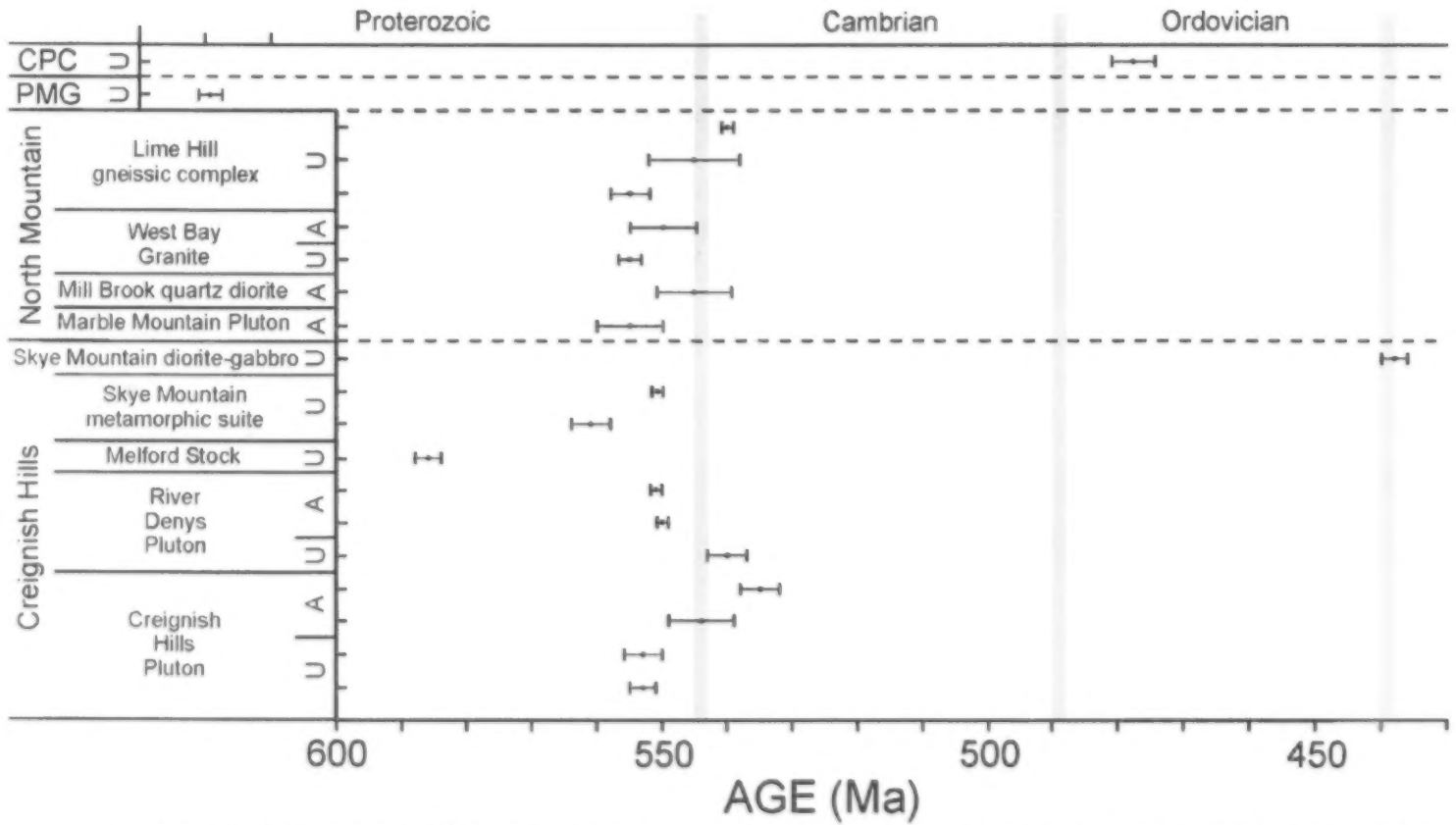

Figure 4. Compilation of U-Pb (zircon) and $^{40}Ar/^{39}Ar$ (hornblende) ages (with error bars) interpreted to indicate crystallization ages of igneous and meta-igneous units in the study area. Data were compiled from the present study and Keppie *et al.* (1990, 1998a, b), Sangster *et al.* (1990), and White *et al.* (2001). Time scale is after Okulitch (2002). Abbreviations: A, $^{40}Ar/^{39}Ar$ (hornblende) age; U, U-Pb (zircon) age; CPC, Cape Porcupine Complex; PMG, Pringle Mountain Group.

mostly of quartz, plagioclase and biotite. It is interpreted as an orthogneiss based on its homogeneous appearance in outcrop and on the presence of relict weakly zoned plagioclase grains visible in thin section. A relatively high Th/U ratio (mostly >0.5) in the zircon is also consistent with an igneous origin. The zircon population obtained from the sample is characterized by colourless, good-quality euhedral and subhedral prisms ranging from equant to elongate with length to breadth ratio of 3:1 to 4:1. Many equant grains are distinctly zoned with an apparent euhedral overgrowth component, but this component is not present on most long prisms. Four fractions consisting of long prisms (length:breadth >3:1), both with and without tiny fluid inclusions, are concordant or near-concordant at 565-560 Ma (Fig. 2a). Their average $^{207}Pb/^{206}Pb$ age of 561 ± 3 Ma is interpreted as the igneous crystallization age of the tonalite, although we acknowledge that a slightly older age of ca. 565 ± 3 Ma (based on the $^{206}Pb/^{238}U$ age of analysis Z1) is possible. Two additional fractions (1 and 4 grains each) of equant, colourless grains give discordant results, indicating mid-Proterozoic inheritance (Fig. 2a).

Granite of the Creignish Hills Pluton was sampled for dating on a logging road in the south-central part of the Creignish Hills (UTM coordinates 5071750N, 626375E). Sample SMB02-79 is typical of the medium- to coarse-grained monzogranitic unit that forms most of the pluton (White *et al.*, 1990). It consists of quartz, K-feldspar (perthitic orthoclase), and plagioclase in approximately equal proportions, with minor biotite and hornblende. It yielded abundant equant to 2:1, euhedral, four-sided zircon prisms of varying size. Fluid inclusions are relatively common and opaque mineral inclusions were also observed. Four concordant or near-concordant single grain and multigrain fractions have an average $^{207}Pb/^{206}Pb$ age of 553 ± 3 Ma (Fig. 2b), which we interpret as the crystallization age of the granite.

The West Bay Granite was sampled in a quarry at the southwestern tip of North Mountain (UTM coordinates 5066850N, 641000E). The dated sample (SMB02-83) is coarse-grained monzogranite, with K-feldspar megacrysts up to 5 cm in length. Mafic minerals (biotite and possibly hornblende) have been replaced by chlorite. The zircon population in this sample appears identical to that for sample SMB02-79, and three near-concordant single grain and 2-grain fractions yield an identical crystallization age of 553 ± 2 Ma (Fig. 2c).

Significance

The 565-561 Ma age for zircon from the Skye Mountain gneiss is similar to ages obtained from some granodioritic, dioritic, and tonalitic plutons elsewhere in the Bras d'Or terrane (Dunning *et al.*, 1990). It is also similar to the metamorphic titanite age reported by Bevier *et al.* (1990) from orthogneiss in the proposed correlative Brookville Gneiss of southern New Brunswick, but younger than the ca. 605 Ma crystallization age of that orthogneiss. The new age constrains the age of paragneissic units of the Bras d'Or Gneiss, from which anatectic components had previously yielded ages of ca. 550-540 Ma (Sangster *et al.*, 1990; Keppie *et al.*, 1998a), to greater than ca. 565 Ma.

The new U-Pb ages from granitic units confirm correlation between the Creignish Hills and West Bay plutons, as assumed previously based on petrological similarities (Raeside and Barr, 1990; Justino and Barr, 1994). However, they disprove the proposed correlation between these granitic plutons and petrologically similar granites farther to the northeast in the Bras d'Or terrane at Kellys Mountain and Cape Smokey, which have yielded younger ages of about 495 Ma (Dunning *et al.*, 1990). The new ages show that the granitic rocks of the Creignish Hills and North Mountain areas are co-genetic with the associated dioritic and granodioritic units that have given similar ages (Fig. 4), and did not form in a separate, younger igneous event, as previously postulated (White *et al.*, 1990; Raeside and Barr, 1990).

Sporting Mountain Area

Geological Summary

The Sporting Mountain area consists of mafic to felsic pyroclastic rocks and flows and tuffaceous

sedimentary rocks that occur around the periphery of the granodioritic Sporting Mountain Pluton (Fig. 5). The volcanic and sedimentary rocks were named the Pringle Mountain Group by Sexton (1988) and Barr *et al.* (1996). No geochronological work had been done previously in this area, but on the basis of similarity in rock types, the Pringle Mountain Group was assumed to correlate with volcanic and sedimentary units in the East Bay Hills and Coxheath Hills (Fig. 5) which had yielded ages of ca. 620 Ma (Bevier *et al.*, 1994).

New logging roads have resulted in improved access and new exposures of the volcanic and sedimentary rocks in the southwestern part of the Pringle Mountain Group, and mapping in 2001 and 2002 led to an improved interpretation of unit distribution (Giles *et al.*, 2002).

New U-Pb (Zircon) Age

Dated sample SMB01-33 was collected from a distinctive flow-banded rhyolite unit in a roadside outcrop in the southern part of the Sporting Mountain block (UTM coordinates 5061375N, 651625E). It consists of scattered euhedral plagioclase phenocrysts in a very fine-grained quartzofeldspathic groundmass. The zircon population consists of colourless, long (>4:1 length:aspect ratio) prisms, and colourless, equant to 2:1, multifaceted prisms, some with minor tip overgrowths. Grain quality is good to excellent (i.e. mostly to completely lacking cracks and/or fluid- or mineral-inclusions). Three single-grain fractions and a 3-grain fraction of the long prisms and a single multifaceted grain were analyzed. The two most concordant fractions closely overlap on concordia, and their average $^{206}Pb/^{238}U$ age of 619 ± 2 Ma is taken as the crystallization age of the rhyolite (Fig. 2d). The remaining fractions lie on a mixing line to ca. 1330 Ma and indicate an influence of mid-Proterozoic inheritance on these analyses.

Significance

The new age is consistent with the previously assumed correlation of the Pringle Mountain Group with volcanic-sedimentary units in the East Bay Hills and Coxheath Hills. This demonstrated correlation emphasizes the potential of the Sporting Mountain area for porphyry- and vein-type sulphide deposits like those in the Coxheath Hills. It also confirms that the units of the Sporting Mountain area are not similar in age to units in the North Mountain area, as has been implied in some work (e.g. Keppie *et al.*, 1990) and hence supports the presence of the Mira-Bras d'Or terrane boundary.

Petit-de-Grat area

Geological Summary

Most of Isle Madame and Petit-de-Grat Island on the southern tip of Cape Breton Island (Figs. 1, 6) consists of Carboniferous sedimentary rocks of the Horton and Windsor groups (Giles *et al.*, 2002). However, southern Isle Madame also includes mylonitic amphibolite, granite, and garnet-sillimante schist in fault-bounded slivers (Fig. 6). Southern Petit-de-Grat Island contains fault-bounded areas of polymictic volcaniclastic conglomerate, rare basaltic flows, and mafic dykes assigned to the Middle Devonian Glenkeen Formation of the Guysborough Group (White *et al.*, 1998a, b; Giles *et al.*, 2002). Although distinction between the older conglomerate and younger conglomerate units of the Horton Group is difficult in this area, the presence of volcanic rocks and granitic intrusions (Petit-de-Grat Pluton; Barr *et al.*, 1984) distinguishes the older unit (Fig. 6). Pelitic units around the Petit-de-Grat pluton are contact metamorphosed and contain cordierite porphyroblasts.

Green Island, located 2 km offshore from Petit-de-Grat Island (Fig. 6) consists of layered amphibolite and granite sheets. Hornblende from the amphibolite previously yielded a $^{40}Ar/^{39}Ar$ plateau age of ca. 391 Ma (Keppie, 1982).

New U-Pb (Zircon) Age

Sample SMB01-42 was collected from near the northern margin of the Petit-de-Grat Pluton (UTM coordinates 5039495N, 661875E). It is of syenogranite composition with about 60% K-feldspar, and consists of porphyroclasts of quartz

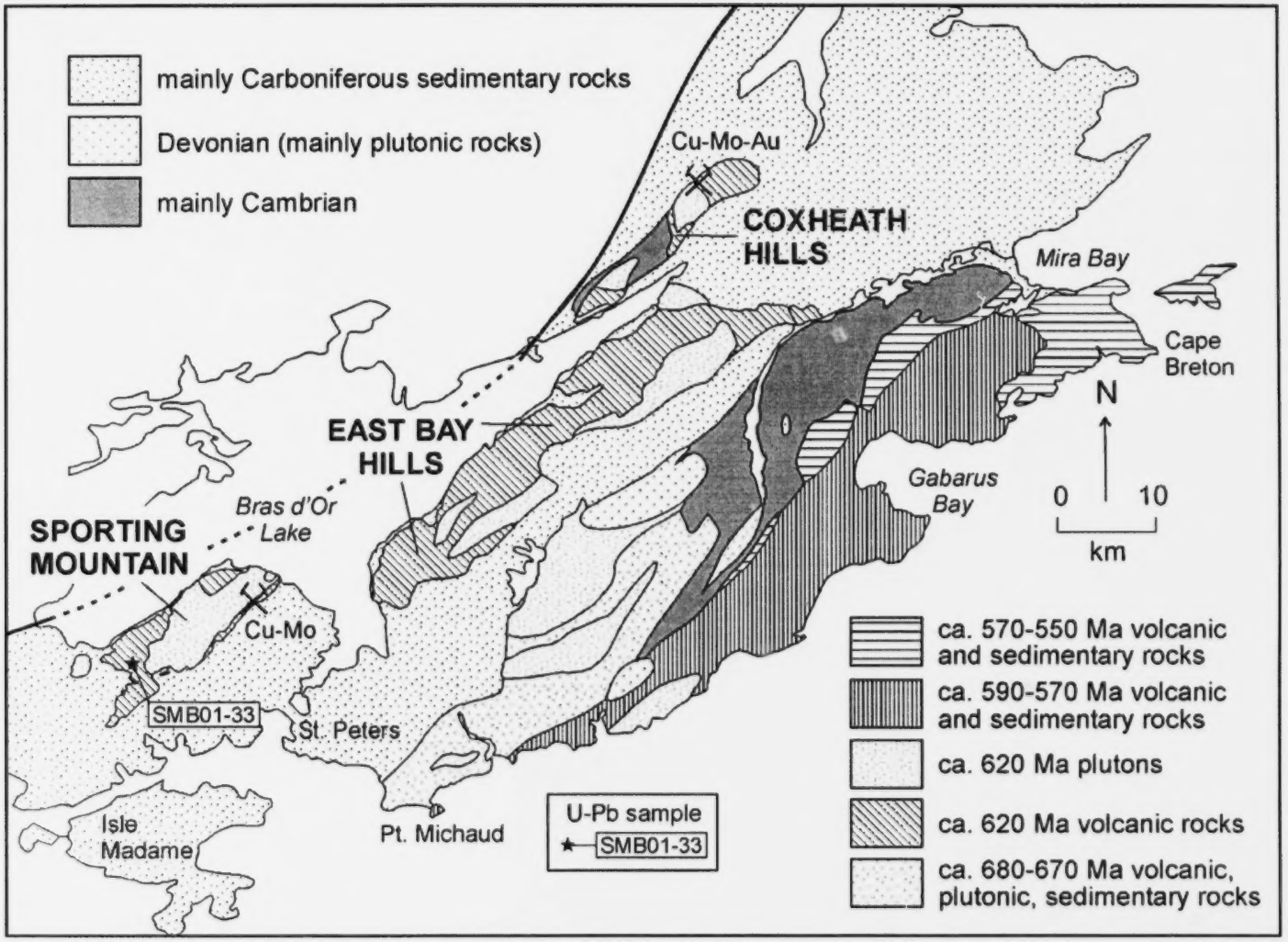

Figure 5. Simplified geological map of southeastern Cape Breton Island (after Barr *et al.*, 1996) showing the location of the Sporting Mountain area relative to other volcanic-sedimentary-plutonic belts of the Mira terrane. The location for dated sample SMB01-33 is indicated.

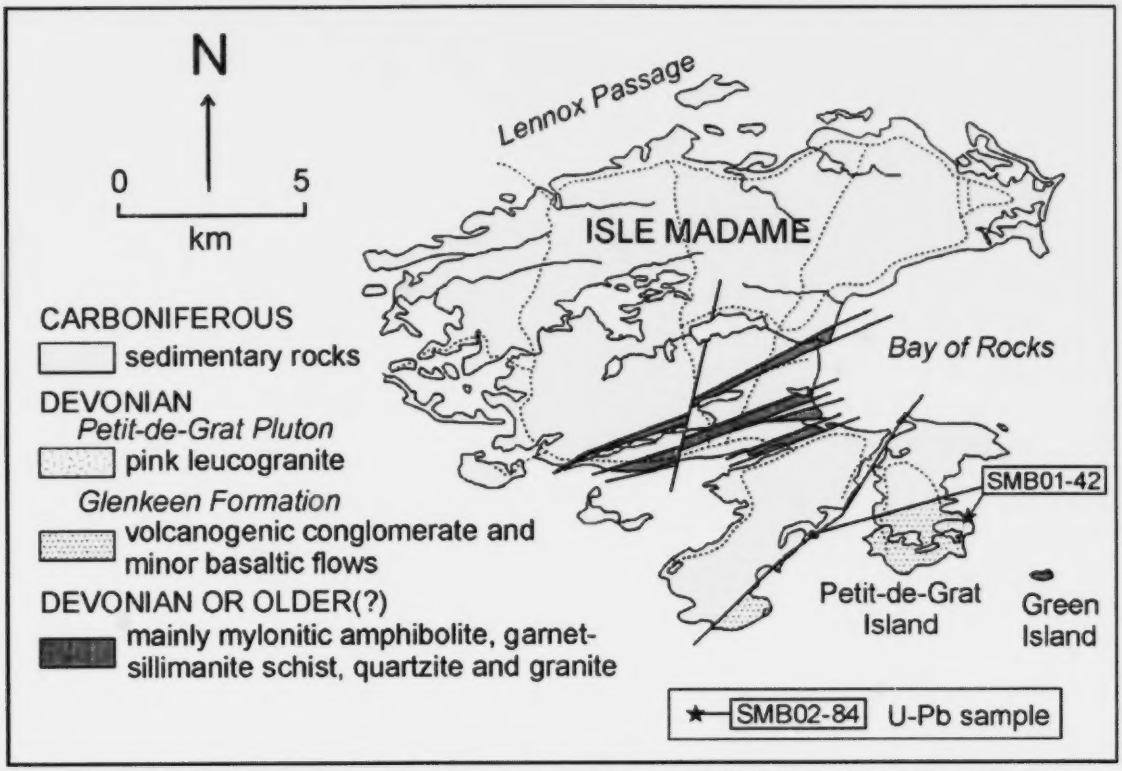

Figure 6. Simplified geological map of the Isle Madame - Petit-de-Grat area (after Giles *et al.*, 2002). The location for dating sample SMB01-42 is indicated.

and K-feldspar set in a matrix of granulated quartz and feldspar. Abundant small euhedral to anhedral, colourless to light brown, mostly equant prisms dominate the zircon population. Grain quality is moderate to good. Despite intragrain variations, the recovered zircons appear to form a single igneous population. Rare larger grains were not analyzed and may be inherited. Four multigrain fractions are concordant within uncertainty and have very similar $^{206}Pb/^{238}U$ ages. A crystallization age of 373 ± 1 Ma (Fig. 2e) is assumed, based on average $^{206}Pb/^{238}U$ age. Two multigrain fractions of the same material are significantly younger, perhaps reflecting Pb loss.

Significance

A U-Pb zircon age of ca. 373 Ma for the Petit-de-Grat Pluton, and the presence of a contact aureole in the surrounding sedimentary rocks, show that the host rocks are older than and, hence, not part of the Late Devonian-Carboniferous Horton Group. The age confirms the speculation by White and Barr (1998a, b) that these rocks are part of the Glenkeen Formation and, hence, that the Guysborough Group of northern mainland Nova Scotia extends into southern Cape Breton Island. If so, then the fault-bounded slivers of metamorphic rocks in the Isle Madame area may originate along the Avalon - Meguma terrane boundary, as previously suggested by Barr *et al.* (1992) and Barr and White (1998a) based on petrological similarities to rocks in faulted slivers on the margins of the Guysborough block (Fig. 1) and elsewhere to the west.

Cape Porcupine Area

Geological Summary

The Cape Porcupine Complex (White *et al.*, 2001)

consists of metasedimentary, metavolcanic, and granitoid rocks (Fig. 7). A granitoid belt in the west includes alkali feldspar granite to monzogranite and magnetite-rich quartz syenite in thrust-faulted contact with a central belt of metasedimentary rocks. As previously reported (White *et al.*, 2001), granite in the western belt yielded a U-Pb (zircon) age of 610 ± 3 Ma. The metasedimentary unit consists of phyllonite from which two whole-rock $^{40}Ar/^{39}Ar$ ages of about 365-370 Ma have been obtained (P. Reynolds, personal communication, 2002; Teniere, 2002). They provide a minimum age for this unit. A mylonitic rhyolite unit occurs in faulted contact with the metasedimentary unit and with varied granitic rocks that form the eastern part of the complex (Fig. 7). The eastern granitic unit varies from equigranular and relatively undeformed to mylonitic.

New U-Pb Data

Three attempts to date samples from the meta-rhyolite unit were unsuccessful due to an absence of zircon. As an alternative, sample SMB02-84 was collected from the granitic unit to the east (Fig. 7). It is brecciated mylonitic alkali feldspar granite, in which the original texture was coarse-grained, but now consists of quartz ribbons around K-feldspar clasts. No mafic minerals are present. The zircon population in this sample consists of colourless, equant, euhedral prisms of good to excellent quality. Most are four-sided and are characterized by either igneous growth zoning or metamorphic overgrowths on igneous cores. Five multigrain fractions have an average $^{207}Pb/^{206}Pb$ age of 478 ± 3 Ma (Fig. 2f), which we interpret as the igneous crystallization age of the granite protolith. The consistency of the age data strongly suggests that igneous growth zoning characterizes the zircon population.

Significance

An unequivocal intrusive relationship cannot be demonstrated between the dated granitic unit and the meta-rhyolite of the Cape Porcupine Complex, although their close association suggests that they might be closely related in age. In any case, the age of the granite confirms that the granitoid rocks in the eastern part of the complex are not related to those that form the western part of the complex, which are much older at ca. 610 Ma (White *et al.*, 2001).

The new age supports the idea that the N-S mylonite zone through the complex may be evidence for the Paleozoic position of the Canso fault, which offsets terranes of Cape Breton Island relative to those of northern mainland Nova Scotia (Fig. 1). However, it does not shed light on the position of the Cape Porcupine complex in the terrane collage because igneous rocks of ca. 478 Ma (Early Ordovician; Okulitch, 2002) are not known in any of the surrounding areas. It was previously recognized that the presence of ca. 610 Ma granite suggests the possibility of an Avalon terrane connection, whereas the metasedimentary rocks that form the central belt of the complex look like some of the low-grade components of the Blues Brook Formation in the Creignish Hills. However, ca. 478 Ma granite is not known to occur in either of those areas, so the terrane affinity of the Cape Porcupine complex remains uncertain.

Conclusions

Combined with previously known ages, the new data provide a much more complete picture for ages of rock units in the pre-Carboniferous basement blocks of the study area (Fig. 4). The increasingly well documented and consistent differences in unit ages support the distinction between the Mira (Avalon) and Bras d'Or terranes, originally based on lithological variations and other data (Barr and Raeside, 1989; Barr *et al.*, 1998). The age of 561 ± Ma for orthogneiss in the Skye Mountain metamorphic suite provides a maximum age for the high-grade metamorphic event in the Bras d'Or terrane that formed the gneissic rocks, an event that is not recorded in the Mira (Avalon) terrane.

The ca. 373 Ma age for the Petit-de-Grat Pluton confirms the link between northern mainland Nova Scotia and the southern tip of Cape Breton Island, and confirms that geological complexity in that area is linked to interaction between the Mira (Avalon) and Meguma terranes. However, the ca. 478 Ma age from mylonitic

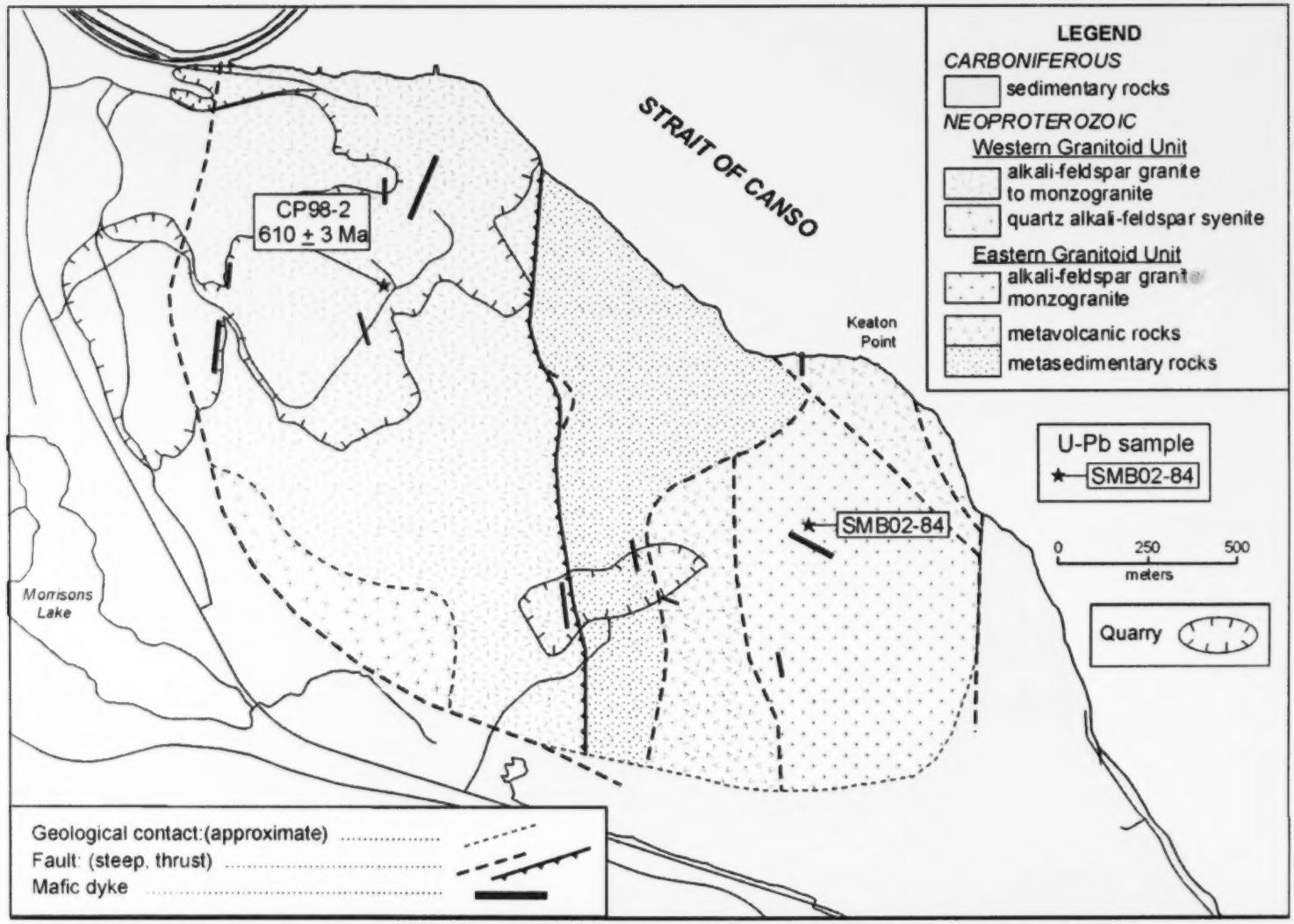

Figure 7. Geological map of the Cape Porcupine Complex (after White *et al.*, 2001). Locations are shown for dating sample SMB02-84 and previously dated sample CP98-2.

granite in the Cape Porcupine Complex increases the mystery about the origin of that block of pre-Carboniferous basement and its place in the terrane puzzle.

Acknowledgments

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References

Barr, S. M. and Raeside, R. P. 1989: Tectono-stratigraphic terranes in Cape Breton Island, Nova Scotia: Implications for the configuration of the northern Appalachian orogen; Geology, v. 17, p. 822-825.

Barr, S. M., O'Reilly, G. A. and O'Beirne, A. M. 1982: Geology and geochemistry of selected granitoid plutons of Cape Breton Island; Nova Scotia Department of Mines and Energy, Paper 82-1.

Barr, S. M., White, C. E. and Graves, M. 1992: Meguma terrane in southern Cape Breton Island? Atlantic Geology, v. 28, p. 194.

Barr, S. M., White, C. E. and Macdonald, A. S. 1996: Stratigraphy, tectonic setting, and geological history of Late Precambrian volcanic-sedimentary-plutonic belts in southeastern Cape Breton Island, Nova Scotia; Geological Survey of Canada, Bulletin 468.

Barr, S. M., Davis, D. W., Kamo, S. and White, C. E. (in press): U-Pb ages of detrital zircon in quartzite from peri-Gondwanan terranes, New Brunswick and Nova Scotia, Canada; Precambrian Research, submitted December 2002.

Bevier, M. L., White, C. E. and Barr, S. M. 1990: Late Precambrian U-Pb ages for the Brookville Gneiss, southern New Brunswick; Journal of Geology, v. 98, p. 955-965.

Bevier, M. L., Barr, S. M., White, C. E. and Macdonald, A. S. 1993: U-Pb geochronologic constraints on the volcanic evolution of the Mira (Avalon) terrane, southeastern Cape Breton Island, Nova Scotia; Canadian Journal of Earth Sciences, v. 30, p. 1-10.

Campbell, J. E. M. 1991: The geology of the northeastern Creignish Hills, Cape Breton Island, Nova Scotia; M.Sc. thesis, Acadia University, Wolfville, Nova Scotia.

Dallmeyer, R. D. and Nance, R. D. 1990: $^{40}Ar/^{30}Ar$ ages of detrital muscovite within Lower Paleozoic overstep sequences, Avalon composite terrane, southern New Brunswick: implications for extent of late Paleozoic tectonothermal overprint; Canadian Journal of Earth Sciences, v. 27, p. 1209-1214.

Dallmeyer, R. D. and Keppie, J. D. 1993: $^{40}Ar/^{30}Ar$ mineral ages from the southern Cape Breton Highlands and Creignish Hills, Cape Breton Island, Canada: evidence for a polyphase tectonothermal evolution; Journal of Geology, v. 101, p. 467-482.

Davis, D. W. 1982: Optimum linear regression and error estimation applied to U-Pb data; Canadian Journal of Earth Sciences, v. 19, p. 2141-2149.

Dunning, G. R., Barr, S. M., Raeside, R. P. and Jamieson, R. A. 1990: U-Pb zircon, titanite, and monazite ages in the Bras d'Or and Aspy terranes of Cape Breton Island, Nova Scotia: implications for magmatic and metamorphic history; Geological Society of America Bulletin, v. 102, p. 322-330.

Giles, P. S., Naylor, R. D., Teniere, P. J., White, C. E., Barr, S. M. and DeMont, G, J. (in press): Geological map of the Port Hawkesbury area (NTS 11F/11, 11F/06, 11F/07, 11F/10); Nova Scotia Department of Natural Resources, Mineral Resources Branch, Open File Map, scale 1:50 000.

Jaffey, A. H., Flynn, K. F., Glendenin, L. E., Bentley, W. C. and Essling, A. M. 1971: Precision measurement of half-lives and specific activities of

^{235}U and ^{238}U; Physical Review, v. 4, p. 1889-1906.

Jansa, L. F., Pe-Piper, G. and Loncarevic, B. D. 1993: Appalachian basement and its intrusion by Cretaceous dykes, offshore southeast Nova Scotia, Canada; Canadian Journal of Earth Sciences, v. 30, p. 2495-2509.

Justino, M. 1991: Geology and petrogenesis of granitoid rocks in the North Mountain area, southwestern Cape Breton Island, Nova Scotia; M.Sc. thesis, Acadia University, Wolfville, Nova Scotia.

Justino, M. and Barr, S. M. 1994: Petrology, petrogenesis, and tectonic setting of plutonic rocks in the North Mountain area, west-central Cape Breton Island, Nova Scotia; Atlantic Geology, v. 30, p. 47-64.

Keppie, J. D. 1982: The Minas Geofracture; *in* Major Structural Zones and Faults of the Northern Appalachians, eds P. St-Julien and J. Beland; Geological Association of Canada, Special Paper 24, p. 263-280.

Keppie, J. D. (compiler) 2000: Geological map of the Province of Nova Scotia; Nova Scotia Department of Natural Resources, Minerals and Energy Branch, Map ME 2000-1, scale 1:500 000.

Keppie, J. D., Dallmeyer, R. D. and Murphy, J. B. 1990: Tectonic implications of $^{40}Ar/^{39}Ar$ hornblende ages from late Proterozoic-Cambrian plutons in the Avalon Composite Terrane, Nova Scotia, Canada; Geological Society of America Bulletin, v. 102, p. 516-528.

Keppie, J. D., Davis, D. W. and Krogh, T. E. 1998a: U-Pb geochronological constraints on Precambrian stratified units in the Avalon Composite Terrane of Nova Scotia, Canada: tectonic implications; Canadian Journal of Earth Sciences, v. 35, p. 222-236.

Keppie, J. D., Dostal, J., Davis, D. W. and Horton, D. A. 1998b: Earliest Silurian supra-subduction magmatism in central Cape Breton Island; Atlantic Geology, v. 34, p. 113-120.

Keppie, J. D., Dostal, J., Dallmeyer, R. D. and Doig, R. 2000: Superposed Neoproterozoic and Silurian magmatic arcs in central Cape Breton Island, Canada: geochemical and geochronological constraints; Geological Magazine, v. 137, p. 137-153.

King, M. S. 2002: The Mira-Bras d'Or terrane boundary in Cape Breton Island, Nova Scotia: potential field and petrophysical investigations applied to tectonic analysis in the northern Appalachian orogen; M.Sc. thesis, Acadia University, Wolfville, Nova Scotia.

Krogh, T. E. 1973: A low contamination method for hydrothermal decomposition of zircon and extraction of U and Pb for isotopic age determinations; Geochimica et Cosmochimica Acta, v. 37, p. 485-494.

Krogh, T. E. 1982: Improved accuracy of U-Pb ages by the creation of more concordant systems using an air abrasion technique; Geochimica et Cosmochimica Acta, v. 46, p. 637-649.

Marillier, F., Keen C. E. and Stockmal, G. S. 1989: Crustal structure and surface zonation of the Canadian Appalachians: Implications of deep seismic reflection data; Canadian Journal of Earth Sciences, v. 26, p. 305-321.

Milligan, G. C. 1970: Geology of the George River Series, stratigraphy, structure, and economic geology; Province of Nova Scotia, Department of Mines, Memoir 7.

Murphy, J. B., Keppie, J. D. and Hynes, A. J. 1991: The geology of the Antigonish Highlands, Nova Scotia; Geological Survey of Canada, Paper 89-10.

Murphy, J. B., Keppie, J. D., Davis, D. and Krogh, T. E. 1997: Regional significance of new U-Pb ages data for Neoproterozoic igneous units in Avalonian rocks of northern mainland Nova Scotia, Canada; Geological Magazine, v. 134, p. 113-120.

Okulitch, A. V. 2002: Geological time chart, 2002; Geological Survey of Canada, Open File 3040.

Raeside, R. P. and Barr, S. M. 1990: Geology and tectonic development of the Bras d'Or suspect terrane, Cape Breton Island, Nova Scotia; Canadian Journal of Earth Sciences, v. 27, p. 1317-1381.

Sangster, A. L., Hunt, P. A. and Mortensen, J. K. 1990: U-Pb geochronology of the Lime Hill gneissic complex, Cape Breton Island, Nova Scotia; Atlantic Geology, v. 26, p. 229-236.

Sexton, A. 1988: Geology of the Sporting Mountain area, southeastern Cape Breton Island, Nova Scotia; M.Sc. thesis, Acadia University, Wolfville, Nova Scotia.

Teniere, P. 2002: Stratigraphy, structure, and $^{40}Ar/^{39}Ar$ geochronology of the Horton Group in the Lochaber-Mulgrave area, Nova Scotia; M.Sc. thesis, Acadia University, Wolfville, Nova Scotia.

Webster, T. L., Murphy, J. B. and Barr, S. M. 1998: Anatomy of a terrane boundary: an integrated structural, GIS, and remote sensing study of the Late Paleozoic Avalon-Meguma terrane boundary, mainland Nova Scotia, Canada; Canadian Journal of Earth Sciences, v. 35, p. 787-801.

White, C. E. and Barr, S. M. 1998a: Geology of the Guysborough-Mulgrave-L'Ardoise area: a progress report; *in* Minerals and Energy Branch, Report of Activities 1998, eds. D. R. MacDonald and K. A. Mills; Nova Scotia Department of Natural Resources, Report ME 1999-1, p. 105-117.

White, C. E and Barr, S. M. 1998b: Preliminary geological map of Guysborough, Richmond and Antigonish counties (parts of NTS sheets 11E/08, 11F/05, 11F/06, 11F/10, 11F/11, 11F/12 and 11F/15), Nova Scotia, Canada; Nova Scotia Department of Natural Resources, Minerals and Energy Branch, Open File Map ME 1998-1, scale 1:100 000.

White, C. E., Barr, S. M. and Campbell, R. M. 1990: Petrology of the Creignish Hills Pluton, Cape Breton Island, Nova Scotia; Atlantic Geology, v. 26, p. 109-123.

White, C. E., Barr, S. M., Ketchum, J. W. F. and Ethier, M. 2001: Geology of the Cape Porcupine Complex (NTS 11F/11), Guysborough County, Nova Scotia; *in* Minerals and Energy Branch, Report of Activities 2000, ed. D. R. MacDonald; Nova Scotia Department of Natural Resources, Report ME 2001-1, p. 83-93.

The Classic Pennsylvanian Locality of Joggins, Nova Scotia: Paleoecology of a Disturbance-prone Wetland Ecosystem[1]

J. H. Calder and H. Falcon-Lang[2]

The coastal cliff section at Joggins provides an unrivalled record of the terrestrial environment of tropical Euramerica. The 1400 m thick Joggins Formation (Langsettian) records peat-forming wetlands, their transition to open water and periodic sustained change to seasonal drylands, all punctuated by discrete flooding events. The wetlands formed part of a rapidly subsiding, shifting distributary system under a climate of seasonal precipitation flux prone to wildfire. Recent research into their paleoecology indicates that abiotic (allogenic) disturbance inherent to the wetlands exerted a fundamental influence on their paleoecology.

The paleobotanical record represents both mire (lycopsids) and extra-mire (sphenopsids, pteridosperms, gymnosperms and ?progymnosperms) plants partitioned by reproductive strategy. Lepidodendrid lycopsids, framework trees of the wetland ecosystem, are represented by a full spectrum of ecological preferences. Calamitean sphenopsids were an ubiquitous succession to buried lycopsid stands, their persistence in aggradational settings aided by vegetative propagation. The tolerance of seed-bearing pteridosperms and gymnosperms to moisture-deficit in terra firma habitats is a corollary to the advantage accorded reptiles by the amniotic egg.

Terrestrial invertebrates included predators (arachnids), but in the main comprised detritivores (arthropleurids, millipedes, land snails) that served as the major pathway from primary producers (plants) to higher trophic levels (carnivorous tetrapods). Absence of substantive herbivory by tetrapods, inferred by their dentition, suggests that 'modern' trophic interactions had yet to evolve. Baphetid stem tetrapods, probable top predators, as well as terrestrial amphibians and amniotes comprised the tetrapod fauna; some may have predated the largely unstudied but diverse aquatic community within the wetlands. Once hollow lycopsid trees, long held to have served as pitfalls for tetrapods, instead may record an ecological guild within the wetland ecosystem. Spatial and temporal heterogeneity of the environment favoured genetic variation and provided evolutionary opportunity for its terrestrial fauna, recorded by early representatives of invertebrate and vertebrate lineages including the earliest amniotes.

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Mid to Late Devonian Organic-rich Terrestrial Deposits in the Early Fill of the Maritimes Basin, Eastern Canada: Composition, Paleobotany and Source Rock Potential[1]

J. H. Calder, P. K. Mukhopadhyay[2] and D. C. McGregor[3]

The earliest basin-fill of the Maritimes Basin comprises a disparate assemblage of formations, traditionally represented chiefly as co-occurring bimodal volcanics and siliciclastic sediments consistent with early stages of rifting. Widespread development of organic-rich deposits within the basin traditionally have been assumed to have commenced at the Devonian-Carboniferous boundary with the lacustrine to estuarine Horton Group (Tournaisian/early Mississippian). Two spatially disjunct formations, however, bear witness to earlier episodes of terrestrial organic-rich accumulation in the mid and late Devonian: the McAdam Lake Formation (late Emsian-early Eifellian) in the south of the Sydney Basin and the Murphy Brook Formation (?Frasnian-Fammenian), which occurs as a fault-bound outlier within the Cobequid Highlands, south of the Cumberland Basin. The MacAdam Lake strata lie within the oil window, whereas the Murphy Brook sediments are much more mature, having been affected by tectonic and intrusive events along the Cobequid Fault zone. Palynology of organic deposits of the MacAdam Lake Formation records a diverse terrestrial flora of vascular plants comparable with the type Eifelian strata of the Rhineland. At Murphy Brook, the high maturation is problematic for palynology, but past macrofloral studies have identified an herbaceous *Taeniocrada-Drepanophycus-Psilophyton* association. The presence of these Devonian source rocks within the early basin fill, their composition and maturity all have implications for the hydrocarbon potential of the Maritimes Basin and its evolution.

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Late Carboniferous Tropical Dryland Ecosystem, Joggins, Nova Scotia[1]

H. J. Falcon-Lang and J. H. Calder

Museum dioramas usually depict the Late Carboniferous tropical zone as being covered by humid rainforests composed of densely spaced tree-sized lycopsids. However, new evidence from the Langsettian fossil cliffs of Joggins, Nova Scotia suggests that this may only be half the story. At this classic site, grey coal-bearing units deposited in humid wetland coastal plain environments and containing 'normal' lycopsid-dominated rainforest vegetation are interbedded with red bed units. The red bed units, which are the focus of this paper, were deposited in seasonal dryland alluvial environment and contain an unusual floral and faunal assemblage. Depauperate floral remains in the deposits of anastomosing river channels, crevasse splays, and overbank muds are dominated by cordaite gymnosperms (*Cordaites* leaves, *Artisia* pith casts, and woody *Dadoxylon* trunks and branches; >80% of specimens). Present in subordinate numbers are pteridosperms (*Eusphenopteris*), sphenopsids (*Calamites*) and lycopsids (*Sigillaria*). A high proportion of this plant material has been charred in wildfires. Faunal remains associated with waterhole deposits in seasonally dry channels include land snails (*Dendropupa*), giant freshwater clams (*Asterodonta*) and the pelvic girdle and jaw of loxomatid reptiles. These data indicate that Late Carboniferous dryland tropical environments supported low diversity, fire-prone gymnospermous vegetation consisting mostly of shrubs or small trees inhabited by a unique fauna. At Joggins, gymnospermous dryland ecosystems repeatedly alternated with lycopsid wetland ecosystems, perhaps in response to glacial-interglacial climate rhythms.

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Fluid Inclusion Decrepitate Textures in Metamorphic Vein-Gold Deposits and Granitic Pegmatites of the Meguma Terrane, Nova Scotia, Canada: Overlooked Phenomenon or a Local Anomaly[1]

D. J. Kontak[2]

Introduction

The textures of fluid inclusions reflect the P-T conditions at the time of entrapment and their subsequent trajectory in P-T space, as noted from both natural (e.g., Touret and Hartel, 1990; Boullier *et al.*, 1991, 1997; Boullier, 1999) and synthetic (e.g., Pêcher, 1981; Bodnar *et al.*, 1989; Sterner and Bodnar, 1989; Vityk and Bodnar, 1995) inclusion studies. In particular are decrepitate textures that record the re-equilibration of fluid inclusions to new P-T conditions post entrapment (see Vityk and Bodnar (1995) for review). Although reference to decrepitate-type fluid inclusion textures is common in the literature on metamorphic rocks, such reference is uncommon in certain mineralized environments that are inferred to be characterized by high and transient fluid pressures (i.e., large ΔP_{H2O}) , such as in mesothermal gold quartz-vein deposits (Robert *et al.*, 1995) and layered pegmatite-aplite systems (e.g., Kirkham and Sinclair, 1988; Lowenstern and Sinclair, 1996). In this paper two such environments located in the Meguma Terrane of southern Nova Scotia are discussed. It is demonstrated that decrepitate textures present are consistent with the inferred P-T trajectories of the samples, as determined from thermometric analysis. It is suggested, therefore, that such textures are probably common and have hitherto been overlooked or observed but not recognized or reported.

Meguma Vein-gold Deposits

The Meguma gold deposits consist of concordant and discordant quartz veins emplaced into a stratigraphy of interbedded metasandstones and metasiltstones of the Lower Paleozoic Meguma Group. The veins are localized to the hinge zones of upright, open to tight anticlinal structures. Detailed analysis of the veins (Horne and Culshaw, 2001) indicate they formed late in the folding history of the rocks (i.e., ca. 370-380 Ma) during flexural-slip shearing on the fold limbs during a late tightening of the regional folds.

Petrographic study of fluid inclusions from three deposit areas, namely Beaver Dam, Caribou and The Ovens, indicate that in each case a mixed aqueous-carbonic fluid dominates with lesser amounts of a saline aqueous fluid; a methane-rich fluid also occurs at The Ovens. The textures of isolated fluid inclusion populations vary from uniform or negative to highly irregular. In some cases, the shapes are very similar to those noted seen in metamorphic rocks or synthetic inclusions and attributed to re-equilibration under varying pressure conditions (e.g., see Fig. 8 of Sterner and Bodnar, 1989). Consistent with these textures are thermometric measurements in conjunction with stable isotopic ($\delta^{18}O$) analysis of vein quartz that indicate veins formed under conditions of transient P_{fluid} (i.e., few kbars) at uniform temperatures. Similar large variations in P_{fluid}, tending towards supralithostatic, have been noted in other mesothermal systems (e.g., Robert *et al.*, 1995).

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South Mountain Batholith - Aplite-Pegmatite Environment

At Peggys Cove layered aplite-pegmatite sheets occur within biotite leucomonzogranite of the 370 Ma peraluminous South Mountain Batholith, which was emplaced at P = 3.5 kbars. The pegmatites contain core zones or pods of coarse quartz-muscovite-tourmaline. Fluid inclusions in quartz are aqueous (20-25 wt. % equiv. NaCl) and mixed aqueous-carbonic, with the former being of magmatic derivation and the latter mixed magmatic-metamorphic. Fluid inclusion textures vary from negative or equant to planes containing a variety of decrepitate textures; those with stellar shapes being the most prominent and recognizable. The decrepitate textures reflect conditions of re-equilibration and thermometric measurements of the fluid inclusions suggest an isobaric cooling path for the pegmatites, which is consistent with the observed decrepitate textures (Vityk and Bodnar, 1995).

Discussion

The observations noted above clearly indicate that in two contrasting geological environments of similar age (i.e., 370 Ma) in the Meguma Terrane decrepitated inclusions form an important fluid inclusion assemblage. The presence of such an assemblage has important implications in terms of fluid inclusion studies, namely: (1) it constrains the P-T path of the sample; (2) it suggests that inclusions and, therefore, samples have been subjected to very different P-T conditions; and (3) that inclusions cannot be considered as inert systems. Collectively these points raise an important questions regarding the interpretation of fluid inclusions in, for example, mesothermal-type vein quartz environments where fluid cycling and dynamic conditions occur. For example, fluid inclusion studies of mesothermal gold veins generally document a range in T_h data for studied samples, whereas uniform $\delta^{18}O_{quartz}$ data are reported. This apparent contradiction is reconciled if pressure cycling (i.e., isothermal compression) is inferred, which would result in trapping of fluids of variable density, hence resulting in a range for T_h data.

In the case of the pegmatitic environments, two possible scenarios are envisaged. Firstly, pressure fluctuations, which are considered part of the evolution of such systems (Kirkham and Sinclair, 1988; Lowenstern and Sinclair, 1996), may result in overpressures of sufficient magnitude to cause decrepitation. Alternatively, where pegmatites form at mesothermal conditions, the subsequent cooling path (i.e., isobaric) may promote decrepitate textures to form, as suggested for Peggys Cove samples.

In summary, it is suggested that textural observations of fluid inclusions be integrated with thermometric data in order to better constrain the P-T path of samples in mesothermal and deeper settings.

References

Bodnar, R. J., Binns, P. R. and Hall, D. L. 1989: Synthetic fluid inclusions. VI Quantitative evaluation of the decrepitation behaviour of fluid inclusions in quartz at one atmosphere confining pressure; Journal Metamorphic Geology, v. 7, p. 229-242.

Boullier, A.-M. 1999: Fluid inclusions: tectonic indicators; Journal Structural Geology, v. 21, p. 1229-1235.

Boullier, A.-M., France-Lanord, C., Dubessy, J., Adamy, J. and Champenois, M. 1991: Linked fluid and tectonic evolution in the High Himalaya mountains (Nepal); Contributions Mineralogy and Petrology, v. 107, p. 358-372.

Boullier, A.-M., Firdous, K. and Boudier, F. 1997: Fluid circulation related to deformation in the Zabargad gneisses (Red Sea rift); Tectonophysics, v. 279, p. 281-302.

Horne, R. J. and Culshaw, N. 2001: Flexural-slip folding in the Meguma Group, Nova Scotia, Canada; Journal Structural Geology, v. 23, p. 1631-1652.

Kirkham, R. V. and Sinclair, W. D. 1988: Comb quartz layers in felsic intrusions and their relationship to porphyry deposits; *in* Recent Advances in the Geology of Granite-Related Mineral Deposits, eds. R. P. Taylor and D. F. Strong; Canadian Institute of Mining and Metallurgy, v. 31, p. 50-71.

Lowenstern, J. B. and Sinclair, W D. 1996: Exsolved magmatic fluid and its role in the formation of comb-layered quartz at the Cretaceous Logtung W-Mo deposit, Yukon Territory, Canada, Transactions Royal Society of Edinburgh; Earth Sciences, v. 87, p. 291-303.

Pecher, A. 1981: Experimental decrepitation and re-equilibration of fluid inclusions in synthetic quartz; Tectonophysics, v. 78, p. 567-583.

Robert, F., Boullier, A.-M. and Firdaous, K. 1995: Gold-quartz veins in metamorphic terranes and their bearing on the role of fluids in faulting; Journal Geophysical Research, v. 100, p. 12861-12879.

Sterner, S. M. and Bodnar, R. J. 1989: Synthetic fluid inclusions. VII. Reequilibration of fluid inclusions in quartz during laboratory simulated metamorphic burial and uplift; Journal Metamorphic Geology, v. 7, p. 243-260.

Touret, J. L. R. and Hartel, T. H. D. 1990: Synmetamorphic fluid inclusions in granulites; *in* Granulites and Crustal Evolution, eds. D. Vielzeuf and Ph. Vidal; Kluwer Acad Pub, The Netherlands, p. 397-418.

Vityk, M. O. and Bodnar, R. J. 1995: Textural evolution of synthetic fluid inclusions in quartz during reequilibration, with applications to tectonic reconstruction; Contributions Mineralogy and Petrology, v. 121, p. 309-323.

Analysis of Decrepitate Mounds as a Compliment to Fluid Inclusion Thermometric Data: Case Studies from Granitic environments in Nova Scotia and Peru[1]

D. J. Kontak

Introduction

Thermometric analyses, that is ice melting temperatures, of fluid inclusions is a rapid method of obtaining bulk chemical compositions (i.e., wt. % equiv. NaCl) and, as such, is a valuable non-destructive means of estimating fluid chemistry. In addition, integration of carefully measured phase changes (i.e., eutectic measurements) during low-temperature runs with known phase changes in the chemically appropriate binary (e.g., $MgCl_2$-H_2O, $CaCl_2$-H_2O) and ternary (e.g., $CaCl_2$-NaCl-H_2O) systems allows more precise estimates of the solute chemistry of fluid inclusions. However, the difficulty of discriminating between low- to moderate-salinity fluids dominated by NaCl or KCl, as well as limited data for more complex multi-component systems (e.g., Fe, Mn, Sr, Ba) limits estimates of the fluid chemistry. Although a variety of nondestructive and destructive methods are available for determining the major, trace and minor element solute chemistry of fluid inclusions, a relatively simple and efficient method underutilized is analysis of fluid inclusion decrepitate mounds. Although the method was first discussed and applied by Eadington (1974), it was the work of Haynes et al. (1988) on synthetic inclusions that demonstrated that this was a reliable semi-quantitative method to obtained cation and anion analysis of fluid inclusions. Subsequently, Haynes and Kesler (1987) successfully applied decrepitate analysis to the study of MVT-style mineralization in the East Tennessee and Pine Point districts and recognized the importance of reduced S in these systems. More recently, Savard and Chi (1998) used similar methods to analyzed mineralizing fluids that formed the MVT deposits in Maritimes of eastern Canada. In another successful study, Chryssoulis and Wilkinson (1983) applied decrepitate analysis to show that quartz megacrysts in mineralized granite of San Luis Potosi, Mexico, contains fluid inclusions with several wt. % each of Na, K, Ca, Mn, Fe and Ag.

The present study focuses on integrating decrepitate analysis with standard thermometric measurements in order to determine the cation chemistry of fluids in a variety of granitic settings. These examples include greisen Sn-base metal mineralization at East Kemptville, Nova Scotia, a pegmatite-aplite system in the South Mountain Batholith, Nova Scotia, and the San Rafael tin-base metal vein system in Peru. Samples were decrepitated on the fluid inclusion stage (U.S.G.S.-type gas flow) and subsequently imaged and analyzed with an electron microprobe at Dalhousie University, Halifax, using an EDS technique. The decrepitate analysis suggest a distinct fluid chemistry for mineralized versus barren systems that may have implications for exploration.

Environments

East Kemptville, Nova Scotia: The host topaz-muscovite leucogranite occurs as the chemical fractionate of

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the zoned Davis Lake biotite monzogranite, itself part of the large, peraluminous 370 Ma South Mountain Batholith of southern Nova Scotia. The upper contact of the granite, proximal metasedimentary rocks, is marked by a chilled zoned and layered aplite-pegmatites with unidirectional solidification textures (UST's) occur. Mineralization occurs as zoned cassiterite-topaz-sulphide greisens and sulphide veins. Fluid inclusion studies of altered granite, pegmatites, greisens and veins indicates the mineralizing fluids exsolved from an evolved granitic melt at ≤550-600°C with bulk composition of 20-40 wt. % equiv. NaCl. Decrepitate analysis were obtained for quartz and cassiterite from two pegmatites, quartz from a cassiterite-bearing miarolitic cavity, and quartz in a sulphide vein. The data indicate the common cations, in descending order, are Na, K, Fe, Mn, Ca, Sr and Ba; Zn and P were mainly detected in the vein sample. The dominant anion is Cl and minor S occurs. Although discrete phases of halite and sylvite occur, most mounds are mixed Na-K-Fe-Mn-Ca salts. The striking feature of the mounds at East Kemptville is the abundance of cations other than Na and K, in particular those elements that would otherwise go undetected.

Peggys Cove, Nova Scotia: Biotite monzogranite of the 370 Ma South Mountain Batholith occurs in close proximity to the Lower Paleozoic Meguma Group, a thick sequence of metaturbiditic rocks locally enriched in carbonate. The monzogranite is cut by abundant, undulating sheets of zoned aplite-pegmatite. The pegmatites contain comb K-feldspar layers, the aplites have well-developed line-rock texture, and coarse quartz-muscovite-tourmaline pods core pegmatites. Fluid inclusions in pegmatitic quartz are both aqueous (L-V, L-V-Halite) and mixed aqueous-carbonic types. The former are interpreted to be exsolved magmatic brines, whereas the later are considered to involve influx of exocontact fluids derived from Meguma Group sedimentary rocks. Low-temperature measurements (i.e., freezing runs) and projection of results into the $NaCl\text{-}CaCl_2\text{-}H_2O$ ternary indicate three compositional groups of fluid inclusions: (1) a Na(-K) fluid; (2) a Na-Ca fluid; and (3) a Ca-rich fluid. Analysis of decrepitate mounds confirms the three compositional groups in terms of the cationic proportions of Na-K-Ca. The chemistry of the fluid is considered to trace the evolution of a magmatic fluid from early K-rich to one of Na-rich nature that reflects fluid:rock interaction at declining temperatures. The Ca-signature, along with trace amounts of S, reflects the incursion of an exotic fluid equilibrated with the Meguma Group metasedimentary rocks. The chemistry contrasts markedly with that at East Kemptville in that Fe and other cations were not detected.

San Rafael, Peru: In southern Peru, an epizonal, 25 Ma biotite-cordierite monzogranite stock intruding Lower Paleozoic metasandstones and metasiltones contains a high-grade lode tin deposit (ca. 36,685 t tin concentrate in 2000). The mineralization occurs asvertically-zoned, high-grade Sn-Cu chloritic lodes. Abundant, secondary fluid inclusions sporadically distriubuted in the quartz megacrysts contain moderate- to hypersaline fluid inclusions and record a system that first boiled and then underwent dilution due to incursion of meteoric water. A similar fluid evolution is recorded by fluid inclusions hosted by vein quartz and cassiterite. Decrepitate analysis of fluid inclusions in the quartz megacryts indicate three distinct fluid compositions, these being Na-, K- and Ca-rich with the Na-rich fluid most abundant. These fluids are also enriched in other cations, most notably Fe with minor to trace Mn and Mg also present.

Discussion

Analysis of decrepitate mounds is a relatively easy and rapid method for providing additional information on the chemistry of fluid inclusions. An interesting result of this study is that the two tin-base metal mineralized systems are also characterized by the presence of Fe (±Mn±Sr±Ba). Given the relative easy of acquiring such data, it is suggested that it become a more routine method of characterizing the chemistry of fluids during fluid inclusion work. With time, the implications of the Fe-enrichment in mineralized systems may be realized and its implications applied.

References

Chryssoulis, S. and Wilkinson, N. 1983: High silver content of fluid inclusions in quartz from Guadalcaza Granite, San Luis Potosi, Mexico: a contribution to ore-genesis theory; Economic Geology, v. 78, p. 302-318.

Eadington, P. J. 1974: Microprobe analysis of the non-volatile constituents of fluid inclusions; Mineralium Deposita, v. 11, p. 518-525.

Haynes, F. M and Kesler, S. E. 1987: Chemical evolution of brines during Mississippi Valley-Type mineralization: Evidence from east Tennessee and Pine Point; Economic Geology, v. 82, p. 53-71.

Haynes, F. M., Sterner, S. M. and Bodnar, R. J. 1988: Synthetic fluid inclusions in natural quartz: IV. Chemical analyses of fluid inclusions by SEM/EDA: evaluation and method; Geochimica Cosmochimica Acta, v. 52, p. 969-977.

Savard, M. M. and Chi, G. 1998: Cation study of fluid inclusion decrepitates in the Jubilee and Gays River (Canada) Zn-Pb deposits - Characterization of ore-forming brines; Economic Geology, v. 93, p. 920-931.

Thompson, M., Rankin, A. H., Walton, S. J., Halls, C. and Foo, b.N. 1980: The analysis of fluid inclusion decrepitates by inductively-coupled plasma atomic emission spectroscopy: an exploratory study; Chemical Geology, v. 30, p. 121-133.

The Jurassic North Mountain Basalts, Nova Scotia: More Than Just Simple Flood Basalts[1]

D. J. Kontak

The 201 Ma North Mountain Basalt (NMB) is a sequence of continental tholeiitic basalts erupted within a continental rift (Fundy Basin) that has been subdivided into lower, middle and upper flow units (LFU, MFU, UFU, respectively). Petrographically the basalts are medium- to fine-grained with ophitic textures and are variably vitrophyric (≤30 %). Results of ongoing investigations of the features of the NMB are summarized below followed by inferences regarding their nature and origin.

1. The LFU (≤190 to ≤40 m) is a medium- to coarse-grained, massive, columnar jointed basalt of dominantly holocrystalline texture with minor vitrophyre. The top few m are often amygdaloidal and mafic pegmatites local occur with felsic layers (≤2-3 cm). Rarely spectacular Neptunian dykes (≤20-30 cm) are controlled by columnar jointing. Although the LFU forms a prominent valley wall along the Annapolis Valley, this topographic feature diminishes westwards.

2. The MFU contains numerous (4-16), variably thick (≤1 to ≤25 m) flows with a laterally variable composite thickness (150 to 10 m) that decreases westwards. The basalts are fine- to medium-grained and contain abundant, variably textured mesostasis (≤30-40%). The MFU is characterized by a systematic zonation of zeolites occluding primary vugs. Minor amounts of massive, fine-grained, homogeneous, red inter-flow sediment occurs as thin (cm scale) beds, and discordant vein networks or dykes; zeolites cross cut and locally replace the dyke rock.

3. The UFU (≤160 m) consists of at least two or more flows and is similar to the LFU. It is a massive, columnar jointed basalt with a medium- to coarse-grained texture and contains abundant vitrophyre (≤30%). Segregation pipes of 3-5 cm to 1 m occur locally and a pervasive early silica alteration along columnar joints post-dates pipe formation. The distribution of the UFU is poorly constrained with the greatest exposure at the west end and the bottom part only observed along the length of the valley coast line; it is not exposed along the north side of the Fundy Basin.

4. Silica veins overlap zeolite formation and occur in the MFU and UFU The veins form en echelon arrays, occupy brittle structures, are massive to finely laminated, and color varies (clear, cloudy white, green, red). There is a change in orientation from N-S to NE from Long Island to Scots Bay.

5. Disconformably overlying weathered flows of the MFU are red-brown sediments of the Scots Bay and McCoy Brook formations.

The above observations indicate: (1) deposition of NMB in sub-basin of variable thickness, (2) extraction of MFU from a different magma source or one that changed post LFU; (3) sinistral movement along E-W bounding faults, (4) rapid deposition and minor inter-flow exposure to weathering, (5) formation of zeolites from circulating hydrothermal fluids post volcanism.

[1]Atlantic Geoscience Society Colloquium and Annual General Meeting, February 8-9, 2002, Antigonish, Nova Scotia; *in* Program and Abstracts

Segregation Pipes in the Jurassic North Mountain Basalts, Nova Scotia: Implications for Anorogenic Magmatism[1]

D. J. Kontak[2] and J. Dostal[3]

The Jurassic North Mountain Basalts (NMB) of southern Nova Scotia, part of the Central Atlantic Magmatic Province (CAMP) of Marzoli *et al.* (1999) and one of the world's largest volcanic provinces (4.5×10^6 km^2), outcrops for several 100 km along the Bay of Fundy coastline. The ca. ≤400-500 m thick sequence is broken into: (i) a massive lower flow unit (LFU) of ≤170 m, (ii) middle flow unit (MFU) of ≤150 m with several (≤15) thin (≤4-20 m) amygdaloidal flows, and (iii) a massive upper flow unit (UFU) of ≤150 m. The MFU and UFU flow units contain abundant (30-40%) quenched mesostasis, originally residual mafic and felsic melts. Exceptional exposures of segregation pipes occur in the UFU several m above the contact with the MFU. The following features are noted: (i) pipes, of round to oval shape, are 2-4 cm to 1 m width, with size consistent in an area, and vertical dimensions of ≤1 m; (ii) pipe abundance decreases as size increases, (iii) chilled margins occur and internal textures vary from aphanitic to coarse grained, (iv) amygdaloidal texture occurs with infill of silica and zeolites; and (v) pipes may contain fine-grained crystalline quartz or agate (0-90% volume) with replacement textures lacking. Petrographic observations reveal pipes are dominated by basaltic or felsic material with proportions varying, but the felsic type is more abundant. The basaltic type is dominated by calcic plagioclase (An_{50-75})and augitic pyroxene, similar texturally to NMB rock, whereas the felsic type is dominated by granophyre entrained with calcic plagioclase (An_{35-50}), anhedral Fe-rich pyroxene ($Wo_{15-40}En_{10-30}Fs_{50-70}$), felsic glass, and micro-enclaves of mafic melt. Whole rock analysis confirms the nature of the mafic and felsic types, with the former similar in terms of trace (e.g., Zr, Nb, Ba), and REE chemistry to typical NMB, whereas the latter show relative enrichment in the trace and REE elements. We suggest that the pipes represent extraction of immiscible felsic melt, previously documented within the NMB, and therefore may provide evidence of bimodal magmatism on a micro-scale. Extrapolation of these observations to a grander scale offer a means of explaining the association of mafic-felsic magmatism within anorogenic settings, particular intra-continental rift environments.

[1]GAC-MAC Annual Meeting, Saskatoon, *in* Abstracts with Programs, v. 27.
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Nature and Origin of Cornwall-type Clay Mineralization in Southwest Nova Scotia, Canada: The Black Bull Resources Inc. Yarmouth Silica-Kaolinite Deposit[1]

D. J. Kontak[2] and K. Kyser[3]

The southwestern part of the Meguma Terrane of Nova Scotia, underlain by ca. 370 Ma peraluminous granites and Cambro-Ordovician metaturbidites of the Meguma Group (MG), is well known for its granophile mineralization (e.g., East Kemptville Sn-Zn-Cu-Ag). However, recent exploration has delineated extensive reserves of silica-clay mineralization within the same granite batholith, some 10 km from the East Kemptville deposit. Initial reserves of ca. 15 Mt silica (≥98-99% SiO_2) and ca. 4.6 Mt kaolinite (80-85% brightness) are indicated for part of the 6 km strike length of the deposit (100 m depth), with exploration drilling and geophysical surveys indicating considerably larger reserves. The deposit occurs at the southern contact of the SMB with MG metasedimentary rocks and is confined to a northeast-trending brittle-ductile shear zone of ≤1.5 km width, with the mineralized zone ≤200-300 m wide. The intensely deformed (i.e., mylonitic) wall-rock biotite leucomonzogranite is progressively replaced by silica- clay rock, culminating in zones of >98% SiO_2 and >60% kaolinite; there is a border zone of quartz-kaolinite breccia and a core of quartz breccia. Paragenetically, early silicification and feldspar-destructive clay alteration is succeeded by repeated brecciation and quartz formation with concomitant increase in wt. % SiO_2. Fluid inclusion studies indicate minimum entrapment temperatures of 141° to 218°C and salinities of ≤0.8 wt. % eq. NaCl; decrepitate analysis indicate a mixed Na-K fluid chemistry. Imaging of opened fluid inclusions indicates the presence of barite euhedra and kaolinite. $\delta^{18}O$ analysis are +10 to +15‰ for quartz and +15 to +17‰ for kaolinite, whereas δD for kaolinite is -60‰ and -65 to -80‰ for quartz-hosted fluid inclusions. Interpretation of these data favours a two fluid mixing model involving magmatic and meteoric fluids with mineralization occurring at ≤300°C. Comparison with additional geological and geochemical information for strike-parallel mineralization in the area (e.g., Tobeatic Lake, Pb-Ag-Ba-Au) suggests that the mineralized zone is laterally extensive (i.e., 10's km), representing part of an extensive silica-clay-base and precious metal environment in southwestern Nova Scotia. The structurally-controlled mineralization probably occurred shortly after SMB emplacement with incursion of meteoric water along a vertically extensive and active fault structure.

[1]GAC-MAC Annual Meeting, Saskatoon, *in* Abstracts with Programs, v. 27
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Petrology, Age, and Tectonic Setting of the White Rock Formation, Meguma Terrane, Nova Scotia: Evidence for Silurian Continental Rifting[1]

L. A. MacDonald[2], S. M. Barr[2], C. E. White and J. W. F. Ketchum[3]

The White Rock Formation in the Yarmouth area of the Meguma terrane of southern Nova Scotia consists mainly of mafic tuffaceous rocks with less abundant mafic flows, epiclastic and clastic sedimentary rocks, and minor intermediate and felsic crystal tuff. It is divided into seven map units that appear to young from west to east, inconsistent with a previously assumed synclinal structure. The White Rock Formation is flanked on both northwest and southeast by mainly the Cambrian to Lower Ordovician Halifax Formation; the western contact is interpreted to be a sheared disconformity, whereas the eastern contact appears to be a major brittle fault and shear zone that juxtaposes different crustal levels. The granitic Brenton Pluton forms a faulted lens within the eastern shear zone. A felsic tuff from the upper part of the White Rock Formation yielded a U-Pb zircon age of $438^{+3}(-_2)$ Ma, identical within error to published ages for the Brenton Pluton and felsic volcanic rocks near the base of the White Rock Formation in the Torbrook area of western Nova Scotia. The chemical characteristics of the mafic volcanic rocks and associated mafic intrusions consistently indicate alkalic affinity and a continental within-plate setting. The felsic volcanic rocks and Brenton Pluton have chemical characteristics of within-plate anorogenic granitic rocks, and the pluton is interpreted to be comagmatic with the felsic volcanic rocks. The igneous activity may have occurred in response to extension as the Meguma terrane rifted away from Gondwana in the latest Ordovician to Early Silurian. Epsilon Nd values are similar to those in voluminous Devonian plutonic rocks of the Meguma terrane, and the magmas appear to have been derived from similar sources.

[1]*In* Canadian Journal of Earth Sciences, 2002, v. 39, p. 259-277
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Metamorphism and Structure of the White Rock Formation in the Yarmouth Area, Nova Scotia[1]

D. P. Moynihan[2], C. E. White and R. A. Jamieson[2]

The White Rock Formation (WRF) of the Meguma terrane forms a belt of mostly mafic metavolcanic and shallow-marine metasedimentary rocks in the Yarmouth area of Nova Scotia. The WRF, together with the adjacent, comagmatic Brenton Pluton formed during the latest Ordovician to earliest Silurian in a within-plate tectonic setting. Acadian (Devonian) deformation in the Meguma terrane is manifested in NE-trending, upright, regional-scale folds with a well-developed axial-planar cleavage. In the Yarmouth area, a regional synclinal structure is suggested by the presence of Cambrian-Ordovician Halifax Formation either side of the WRF and by magnetic anomaly maps. However, younging directions on the coastal section consistently face southeast and no clear stratigraphic repetition is apparent. The contacts of the WRF with the Halifax Formation lie within broad Alleghenian shear zones. Original contact relations are unclear.

Low-pressure metamorphism accompanied Acadian deformation elsewhere in the Meguma terrane, however mineral assemblages preserved in the WRF of the Yarmouth area suggest metamorphism under moderate-pressure conditions. Metamorphic grade ranges from upper greenschist to lower amphibolite facies in the WRF .Staurolite-bearing pelites are widely developed in the southeastern part of the area and are locally present within the Cranberry Point Shear Zone. Those in the southeast preserve common staurolite-garnet-biotite assemblages, wheareas staurolite appears in association with oligoclase porphyroblasts in the northwest. Peak-metamorphic porphyroblasts overgrow the main regional schistosity (S1) and the well-developed, gently southwest-plunging stretching lineation (L1) throughout the area. Textures in staurolite-oligoclase porphyroblastic pelite within the Cranberry Point Shear Zone indicate peak metamorphism was synchronous with localized crenulation of S1 around steep axes. Peak-metamorphic porphyroblasts pre-date a transposition fabric developed in bounding Alleghenian shear zones. Bounding shear zones juxtapose amphibolite facies rocks of the WRF against greenschist facies Halifax Formation. These shear zones have therefore accommodated significant post-peak- metamorphic displacement and may represent major crustal structures.

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[1]Atlantic Geoscience Society Colloquium and Annual General Meeting, February 8-9, 2002, Antigonish, Nova Scotia; *in* Programs and Abstracts, p. 32

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Sedimentology and Fossil Biota of a Pennsylvanian "Waterhole" Deposit in a Dryland Alluvial Plain Setting, Joggins, Nova Scotia[1]

M. C. Rygel[2], H. J. Falcon-Lang[3], J. H. Calder and M. R. Gibling[2]

Arguably the world's finest Pennsylvanian exposure, the cliffs of Joggins, Nova Scotia are most famous for their fossil lycopod forests preserved within gray-colored, peat-forming wetland deposits. Although less well-known, thick red bed intervals deposited in dryland alluvial plains also form an integral component of the classic Joggins section. The sedimentology and fossil biota of one dryland alluvial plain unit is described, providing important insight into the paleoecology of poorly-understood Pennsylvanian drylands.

The study interval, informally termed the "Hebert beds", comprises five sandy channel-bodies exposed in both the cliff face and the wave-cut platform. Based on their low width to thickness ratios (W T<8) and lack of lateral migration features, the three oldest channel-bodies (3.4-5.7 m thick) are interpreted as fixed-channel deposits. In contrast, the two youngest channel-bodies (1.8-3.5 m thick) have higher W:T ratios (probably ;21), abundant lateral accretion surfaces, and are interpreted as meandering channel-bodies. These five channel-bodies formed under different, but genetically related flow conditions and are interpreted as the deposits a progressively abandoned, anastomosed fluvial system.

Floral remains within the channel fills are dominated by cordaite gymnosperms (*Cordaites* leaves, *Artisia*-type pith casts, and charcoalified pycnoxylic wood). *Calamites* fragments, decorticated lepidodendrid trunks (*Sigillaria*?), and calcareous rhizoconcretions are also locally present. Invertebrate remains comprise shells of the land snail *Dendropupa* and the large freshwater clam *Archanodon westoni*. Vertebrate remains are represented by the pelvic girdle of a large tetrapod and the jaws of a microsaur. This unusual association of fossils within channel-bodies is interpreted as a "waterhole" deposit which provided an important source of water for a variety of organisms during the tropical dry season.

[1]Geological Society of America Annual Meeting, Denver; *in* Abstracts with Programs, v. 34, p. 18
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Stratigraphy and Structure of the Horton Group in the Lochaber-Mulgrave Area, Nova Scotia[1]

P. J. Ténière[2], S. M. Barr[2] and C. E. White

During the summer of 2001, extensive mapping was done in the Lochaber-Mulgrave area of northern mainland Nova Scotia as part of an on-going study of stratigraphy and structure in this complex area, bounded by the Glenroy Fault on the north, the Strait of Canso on the east, the Roman Valley Fault on the south, and pre-Carboniferous rocks of the Antigonish Highlands on the west. Sedimentary rocks in the area are now assigned to the Early Devonian Knoydart Formation, Early Carboniferous Horton and Windsor groups, and Late Carboniferous Mabou Group. The Horton Group underlies most of the map area, and has been divided into four formations (from oldest to youngest): (i) Clam Harbour River Formation (Englands Lake and Goose Harbour Lake members), (ii) Tracadie Road Formation (Half moon Lake and Lincolnville members), (iii) Caledonia Mills Formation, and (iv) Steep Creek Formation. The fluviatile Englands Lake Member consists of fine- to coarse-grained sandstone and polymictic conglomerate, and maroon to green-grey siltstone. The overlying, lacustrine-deposited Goose Harbour Lake Member consists of poorly- to well-laminated green-grey siltstone and shale with interbedded dolomite. The fluviatile Halfmoon Lake Member consists of polymictic conglomerate, pebble sandstone, and quartz arenite with minor interlayered dark grey siltstone. The overlying, lacustrine-deposited Lincolnville Member consists of dark grey laminated siltstone and shale interlayered with minor quartz arenite. Rare Lepidodendropsis plant fossils of Tournaisian age are found in the fine-grained sandstone and shale beds. The overlying Caledonia Mills Formation consists of red to light grey, massive to well-laminated siltstone and sandstone and is interpreted to have been deposited in an arid fluvial environment. The Steep Creek Formation unconformably overlies the Goose Harbour Lake and Lincolnville members and consists of polymictic conglomerate, fine-grained to pebble sandstone, and maroon to dark grey siltstone. All of these units are lithologically similar to those assigned to the Horton Group in the St. Marys Basin. The sedimentary provenance may be confirmed through $^{40}Ar/^{39}Ar$ dating of detrital muscovite grains in the Horton Group sedimentary units.

In comparison to the Horton Group in other areas, the rocks in the Lochaber-Mulgrave area are highly deformed. In addition, most of the area has undergone low-grade regional metamorphism, and cleavage is well developed as a result of accompanying deformation. The western part of the region has open to tight, upright to overturned, northeast-trending folds with well-developed axial planar cleavage. The eastern part has tight to close, upright, north-south-trending folds with moderately developed axial planar cleavage. Folded axial plane traces and scattered cleavage orientations indicate the region has undergone polyphase deformation. The structural complexity in the Lochaber-Mulgrave area may be related to interaction between the Avalon and Meguma terranes during their juxtaposition along the Cobequid-Chedabucto fault system.

[1]Atlantic Geoscience Society Colloquium and Annual General Meeting, February 8-9, 2002, Antigonish, Nova Scotia; *in* Program and Abstracts, p. ?
[2]Department of Geology, Acadia University, Wolfville, NS, Canada B0P 1X0

Preliminary Bedrock Geology of the Tusket (20P/13) Map Sheet, Southwestern Nova Scotia[1]

C. E. White, R. J. Horne and M. S. King[2]

Geological bedrock mapping (1:10 000 scale) related to the Southwest Nova Scotia Mapping Project continued through the summer of 2001 on the Tusket map sheet (20P/13), in southwestern Nova Scotia. The oldest stratified units in the map area are the Cambrian to Early Ordovician Goldenville and overlying Halifax formations of the Meguma Group. The Goldenville Formation occurs in the western part of the map area and consists of grey, thick-bedded, featureless metasandstone that locally contains numerous "vugs" of weathered-out calc-silicate nodules. Black sulphide-rich spotted slate is locally interlayered with the metasandstone. The Halifax Formation consists of grey spotted slate, although textural and lithological features vary depending on metamorphic conditions. As metamorphic grade increases the Halifax Formation is characterized by the development of porphyroblastic staurolite and andalusite granofels and schist. Around the western and northern margins of the Barrington Passage Pluton the Halifax Formation consists of garnet-sillimanite granofels and schist, whereas on the eastern side the formation is migmatitic in character. The contact with the Goldenville Formation is not exposed.

The latest Ordovician to Early Silurian White Rock Formation outcrops in the northwestern margin of the map area. Here it is composed mainly of amphibolite interlayered with staurolite-biotite schist and quartzite. It is separated from the Meguma Group by the Cheboque Point shear zone.

The ca. 375 Ma Barrington Passage Pluton intruded rocks of the Meguma Group in the eastern part of the map area and consists of medium-grained, locally well foliated biotite tonalite gradational to quartz diorite. Dykes of pegmatite and biotite-muscovite granite are common. The northern margin of the pluton has an irregular outline due to the abundance of garnet-sillimanite granofels and schist xenoliths. This area probably represents the roof of the pluton whereas the migmatitic rocks on the east presumably represent deeper depths.

Units in the Meguma Group have been folded into regional, north-trending F_1 folds in the southern part of the map area and northeast-trending F_1 folds in the north, with an axial planar cleavage during the Devonian Acadian Orogeny. Deformation was accompanied by greenschist- to amphibolite-facies metamorphism that resulted in an eastward increase in metamorphic grade from biotite zone in the west to garnet-sillimanite assemblages in the east. The presence of a locally prominant steep to moderately- north and northeast-plunging mineral lineation defined by elongate andalusite and sillimanite in the granofels and quartz rods in the tonalite suggests that the pluton in this area may be syntectonic with respect to regional deformation and metamorphism.

The Late Carboniferous Wedgeport Pluton intruded metasandstone of the Goldenville Formation in the southern part of the map area. It consists of a medium-grained, biotite-bearing monzogranite. Olivine diabase and lamprophyric dykes are rare, but both intrude the Wedgeport Pluton and adjacent Goldenville Formation.

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[1]Atlantic Geoscience Society Colloquium and Annual General Meeting, February 8-9, 2002, Antigonish, Nova Scotia; *in* Program and Abstracts, p. 40

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Appendix 1

Mining Industry Activity in Nova Scotia, 2001

Mining Industry Exploration, Development, Capital and Repair Expenditures

Investment by the mining industry in Nova Scotia is monitored by means of annual surveys of all mining companies having operations or activity in the province. The surveys are carried out by the Nova Scotia Department of Natural Resources (DNR) jointly with Natural Resources Canada (Minerals and Metals Sector - Minerals and Mining Statistics Division), and Statistics Canada (Investment and Capital Stock Division). The Mineral Management Division of DNR actively participates in the Annual Survey of Canadian Mineral Exploration Expenditures and the Annual Survey on Exploration, Development, Capital and Repair Expenditures. Aggregate producers are not included in Table 1.1.

Preliminary figures indicate exploration expenditures in 2001 were $3.2 million, up slightly from 2000 (Table 1.1). Diamond-drilling was down appreciably to 5 100 metres. Capital expenditures at existing mines dropped significantly in 2001 to $8.9 million, while repair and maintenance expenditures were down moderately to $16.8 million.

Mining Leases

There was one new Mining Lease issued in the province during the year. In August, C_2C Zeolite Corporation was issued a Mining Lease for its zeolite property at Stronach Mountain, Annapolis County.

Mining Permits

The department did not issue any new Mining Permits during the year.

Production Information from Mines, Quarries and Other Operations

In 2001, the estimated value of Nova Scotia's mineral production, including secondary mineral

Table 1.1. Mining industry expenditures in 2000 and 2001.

	2000	2001[1]
Mineral Exploration Expenditures (field plus overhead)[2]	$2,964,575	$3,177,805
Exploration diamond-drilling[2]	8 500 m	5 100 m
Exploration drilling - other[1]	N/A	N/A
Mine Complex Development Expenditures (field plus overhead)	$4,250,345	$7,945,857
Capital and Repair Expenditures at Mining Establishments	$43,823,619	$8,907,710
Capital Expenditures	$21,024,157	$16,767,531
Repair and Maintenance Expenditures		

[1] preliminary
[2] includes deposit appraisal

Appendix 1: *in* Mineral Resources Branch Report of Activities 2002, Nova Scotia Department of Natural Resources. Report ME 2003-1, p. 197-211.

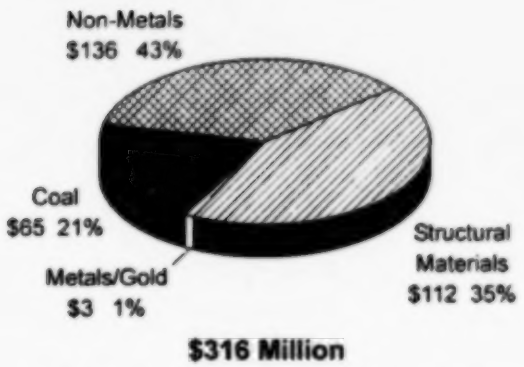


Figure 1.1. Value of mineral production, in millions of dollars and per cent, by commodity group.

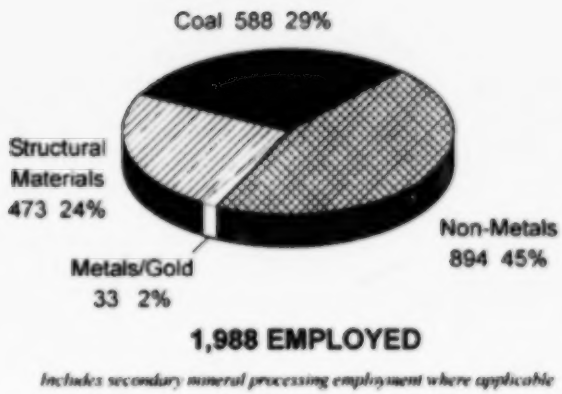


Figure 1.2. Employment, in numbers of persons and per cent, by mineral commodity group.

processing, totaled $316 million (Fig. 1.1), virtually unchanged from $315 million in 2000. The value of aggregate production increased by $23 million and offset reductions in the value of coal, salt and peat moss production. Employment in Nova Scotia's mineral industry totaled 1,988 persons (Fig. 1.2), a 7% decrease from the previous year. The drop in employment is primarily a result of reduced employment in gypsum operations, surface coal operations and in the crushed stone industry.

Nova Scotia's gypsum production was 6.8 million tonnes shipped. This represents a 6% decrease from the 2000 gypsum production. Gypsum is supplied mainly to wallboard plants along the U.S. Eastern Seaboard. Nova Scotia is Canada's largest gypsum producer, accounting for more than 80% of the country's total production.

Nova Scotia's 2001 salt production increased approximately 21% from 2000 to 1.1 million tonnes.

Coal production was up marginally in 2001, to 1.2 million tonnes. These production levels were lower than the historical annual coal production, reflecting the closure of the Phalen underground coal mine in industrial Cape Breton in 1999. A further decrease in coal production is expected in future years due to the loss of the Prince Mine's production, with its closure in late 2001.

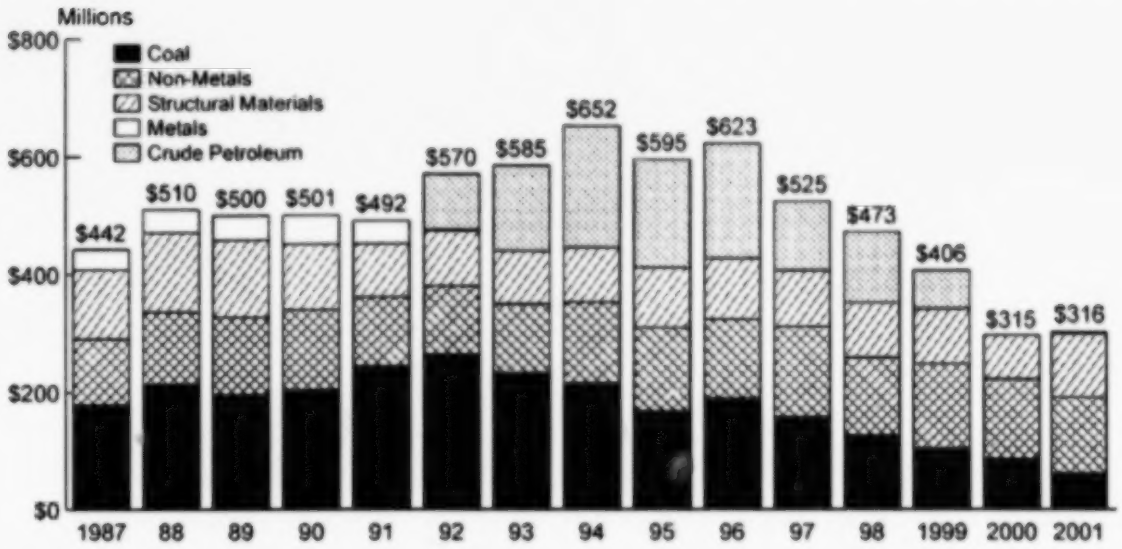
Cement production increased 17% for 2001 to 292,000 tonnes. Overall, aggregate (crushed stone, sand and gravel) production increased by 23% from the year before to 11.7 million tonnes in 2001. Crushed stone production was up 15% while sand and gravel production increased 53%. Peat moss production was lower in 2001 at 2 771 tonnes due to the closure of Clare Organic Products. Clay and shale production was up 20% over 2000 to 32 000 tonnes.

In the years prior to 2000, the value of petroleum production has been included in the overall value of Nova Scotia's mineral production. However, there has been no production of crude oil since 1999, and the production of offshore natural gas is not included in this appendix. The appendix covers non-petroleum sectors of the mineral industry (Table 1.2), providing a description of each mine site. Tables 1.3 to 1.6 provide more detailed information on the production of different commodities. Site locations are shown on the accompanying maps, Figures 1.4 and 1.5. Production data are for the calendar year 1 January 2001 to 31 December 2001.

Metal and Gold Mines

Metal Mines

There were no producing metal mines in the province in 2001.



Includes secondary mineral processing where applicable

Figure 1.3. Historical trend in the value of mineral production in Nova Scotia, 1987-2001.

Gold Mines

DUFFERIN RESOURCES INCORPORATED

Manager: W. Coles (Envirogold Technologies Inc.)
Address: Dufferin Resources Incorporated
P. O. Box 2020
Windsor, N. S. B0N 2T0
Production: 7,287 ounces (226 kg) of gold
Employees: 33

The Dufferin Mine at Port Dufferin resumed production during 2001. Gold production of 7,287 ounces was achieved during the year. The mine is an underground trackless mine and the ore is treated in a processing plant at the mine site. Envirogold Technologies Inc. operated the mine under an arrangement with the Mining Lease holder, Dufferin Resources Incorporated. Operations were temporarily suspended at the end of 2001 and did not resume during 2002.

Coal Mining Operations

During 2001, there was one underground coal mine, four surface coal mines, and a coal recovery project operating in the province. Production information for the mines is summarized in Table 1.3. The summaries below give brief details of the underground and surface coal mines operating in Nova Scotia.

Underground Coal Mine

CAPE BRETON DEVELOPMENT CORPORATION

Manager: T. MacNeil, Mine Manager, Prince Colliery
Address: P. O. Box 2500
Sydney, N. S. B1P 6K9
Raw Coal
Production: 1,030,172 tons (934,566 tonnes) of coal
Employees: 500

The Cape Breton Development Corporation is a federal Crown Corporation that operated the underground Prince Mine at Point Aconi, Cape Breton County. The mine began underground production from the Hub Seam in 1975, initially using room and pillar methods. Mechanized retreat longwall operations began in 1980. The corporation's coal production was supplied to Nova Scotia Power Inc.

Table 1.2. Summary of Nova Scotia mineral production, 2000 and 2001.

DESCRIPTION	2000 VALUE ($ thousands[1])	2000 EMPLOYMENT*	2001 VALUE ($ thousands[1])	2001 EMPLOYMENT*
METALS				
Gold	0		3,088	33
Total metals	0	10	3,088	33
INDUSTRIAL MINERALS				
(Non-Metals)				
Anhydrite	2,202		***	
Barite	140		***	
Gypsum	76,340		75,466	
Limestone[2] and Dolomite	5,444		5,030	
Peat	2,559		***	
Salt**	54,048		***	
Silica	4,143		***	
Total Non-Metals	144,876	884	135,618	894
(Structural Materials)				
Dimension Stone	300		***	
Cement**	36,750		***	
Clay Products**	6,000		***	
Crushed Stone	41,795		58,811	
Sand & Gravel	8,236		14,096	
Total Structural Materials	93,081	628	112,430	473
Total Industrial Minerals	237,957	1,512	248,048	1367
FUELS				
Coal	76,880	625	65,000	588
TOTAL MINERAL PRODUCTION	314,837	2,147	316,136	1,988
CHANGE FROM PREVIOUS YEAR	-22%	-26%	+0.4%	-7%

[1] Estimated from Department of Natural Resources sources
[2] Does not include the value of limestone quarried for cement production
* Average number of persons during production period
** Processed or manufactured value
*** Value not shown, but included in total
Note: Production represents shipments; numbers may not add to totals due to rounding

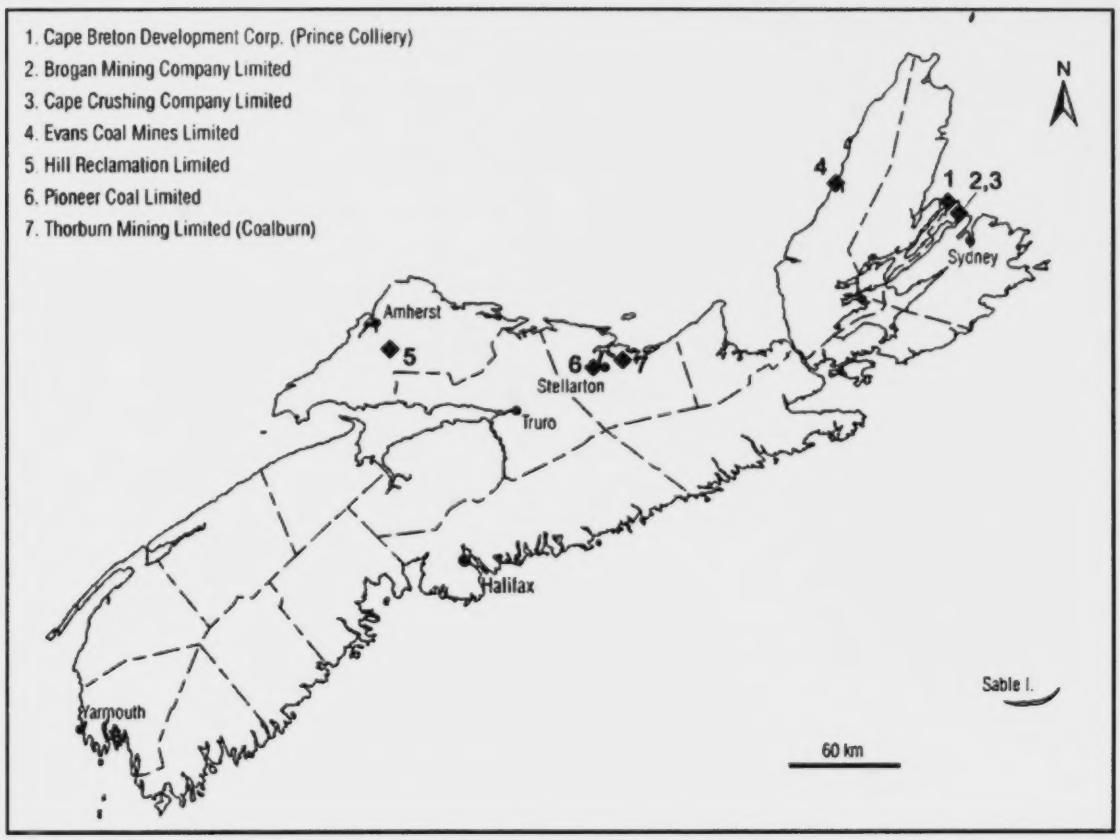


Figure 1.4. Location of coal mines in Nova Scotia, 2001.

During 2001, the Prince Mine operated until November, when coal production was stopped. Production came primarily from the No. 1 North longwall panel, which was completed at that time. Development work had been suspended during the year, and the mine openings were closed before the end of the year.

Surface Coal Mines

PIONEER COAL LIMITED

Manager: C. Chisholm
Address: P. O. Box 1328
Antigonish, N. S. B2G 2L7
Production: 178,202 tons (161 664 tonnes) of coal
Employees: 34

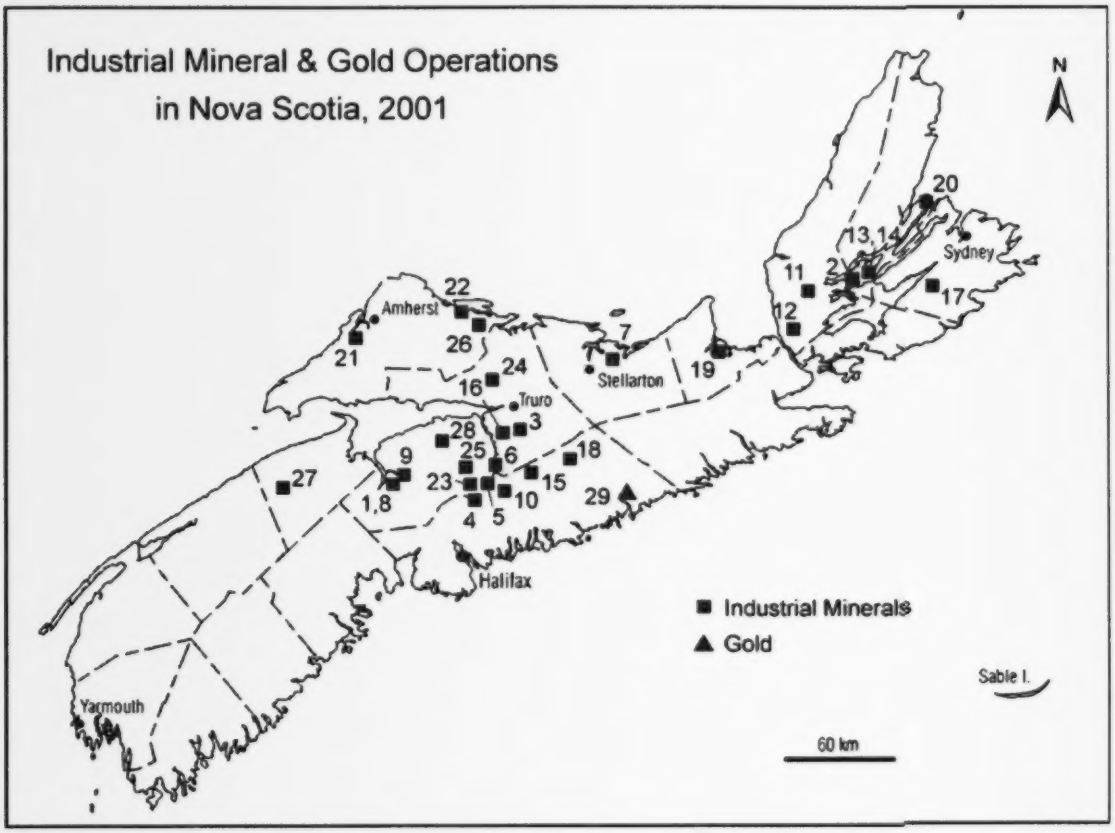
Pioneer Coal mines coal from two seams at the Stellarton surface mine, Pictou County. The company has been mining on the Foord Seam since 1996 and began mining on the Cage Seam in 2001. The Foord Seam is approximately 12 metres thick and the Cage Seam is about 5 metres thick. Two mining methods were used at Stellarton in 2001, conventional surface mining and highwall mining. Conventional surface mining employs mechanical equipment to break the coal and overlying rock. The material is excavated using hydraulic excavators, conveyors and off-road haul trucks. The operator successfully implemented use of its highwall mining system on the Foord Seam at Stellarton in 2001. The highwall miner is a remotely controlled system that extracts coal in a series of headings driven from the coal seam face in a surface cut.

The company conducted mining operations at the site from February through June and September through December. Production was suspended for

Table 1.3. Coal production for the calendar year 2001.

COMPANY	MINE NAME	LOCATION	PRODUCTION		TOTAL NUMBER EMPLOYED[1]	APPROX. VALUE($)[2]
			TONS	TONNES		
UNDERGROUND MINING						
Cape Breton Development Corp. (CBDC)	Prince Mine	Point Aconi, Cape Breton County	1,030,172	934 566	500	
Total (underground)			1,030,172	934 566	500	
SURFACE MINING						
Brogan Mining Company Limited	Little Pond Mine	Alder Point, Cape Breton County	53,991	48 980	20	
Cape Crushing Company Limited	Merritt Point Mine	Alder Point, Cape Breton County	23,354	21 187	10	
Hill Reclamation Limited		Springhill, Cumberland County	8,547	7 754	6	
Pioneer Coal Limited	Stellarton Mine	Stellarton, Pictou County	178,202	161 664	34	
Thorburn Mining Limited	Coalburn Mine	Coalburn, Pictou County	68,012	61 700	18	
Total (surface)			332,106	301 285	88	
TOTAL FOR ALL COAL PRODUCERS			1,362,278	1 235 851	588	65,000,000

[1]personnel employed in clerical, supervisory, etc. positions as well as mining personnel.
[2]estimated from Nova Scotia Department of Natural Resources sources
NOTE: Production represents shipments; numbers may not add to totals due to rounding



Anhydrite
1. Fundy Gypsum Co.
2. Little Narrows Gypsum Co.

Barite
3. E-Z-EM Canada Inc.

Clay and Shale
4-7. Shaw Brick, a member of the Shaw Group Limited

Gypsum
8-9. Fundy Gypsum Co.
10. National Gypsum (Canada) Ltd.
11-12. Georgia-Pacific Corp.
13-14. Little Narrows Gypsum Co.
15. Tusket Mining Incorporated

Limestone & Dolomite
16. Lafarge Canada Inc.
17. Nova Scotia Power Incorporated
18. Mosher Limestone Co. Ltd.
19. Ridge Brokers Ltd.
20. Scotia Limestone Ltd.

Salt
21. Sifto Canada Inc.
22. The Canadian Salt Company Limited

Silica Sand
23. Shaw Resources, a member of the Shaw Group Limited
24. Lafarge Canada Inc.

Dimension Stone
25. Scotia Slate Products Ltd.
26. Wallace Quarries Ltd.

Peat Moss
27. Annapolis Valley Peat Moss Co.
28. MacDonald Peat Moss Limited

Gold
29. Dufferin Resources Inc.

Figure 1.5. Location of industrial mineral and gold operations in Nova Scotia, 2001.

Table 1.4. Industrial minerals production for the calendar year 2001.

COMPANY	LOCATION	PRODUCTION		TOTAL NUMBER EMPLOYED[1]	APPROXIMATE VALUE ($)[2]
		TONS	TONNES		
GYPSUM					
Fundy Gypsum Company	Miller Creek and Wentworth Road, Hants County	1,729,580	1 569 065	188	
Georgia-Pacific Canada, Inc.	Sugar Camp, Inverness County	1,492,984	1 354 426	114	
Little Narrows Gypsum Company	Little Narrows, Victoria County	1,039,566	943 088	87	
National Gypsum (Canada) Limited	East Milford, Halifax County	3,281,296	2 976 772	100	
Total (gypsum)		7,543,426	6 843 351	489	75,466,000
ANHYDRITE					
Fundy Gypsum Company	Wentworth Road, Hants County	33,694	30 567	included in gypsum	
Little Narrows Gypsum Company	Little Narrows, Victoria County	49,809	45 186	included in gypsum	
Total (anhydrite)		83,503	75 753		*
SALT					
The Canadian Salt Company Limited	Pugwash, Cumberland County	1,124,484	1 020 125	218	
Sifto Canada Inc.	Nappan, Cumberland County	94,446	85 681	49	
Total (salt)		1,218,930	1 105 806	267	*
LIMESTONE AND DOLOMITE					
Lafarge Canada Inc.	Brookfield, Colchester County	496,823	450 715	20	
Mosher Limestone Company Limited	Upper Musquodoboit, Halifax County	35,374	32 091	23	
Nova Scotia Power Incorporated	Glen Morrison, Cape Breton County	131,950	119 704	10	
Ridge Brokers Limited	Southside Harbour, Antigonish County	11,023	10 000	1	
Scotia Limestone Limited	Kellys Cove, Victoria County	6,614	6 000	2	
Total (limestone and dolomite)		681,784	618,510	56	5,030,000[4]
BARITE					
E-Z-EM Canada Inc.	Brookfield, Colchester County	5000	4536	16	
Total (barite)		5000	4536	16	*

Table 1.4. Continued.

COMPANY	LOCATION	PRODUCTION TONS	PRODUCTION TONNES	TOTAL NUMBER EMPLOYED[1]	APPROXIMATE VALUE ($)[2]
CLAY AND SHALE					
Shaw Brick (a member of the Shaw Group Limited)	Lantz and Milford, Hants County New Glasgow, Pictou County	35,936	32 601	see clay products Table 1.5	n/a[5]
Total (clay and shale)		35,936	32 601	see clay products Table 1.5	n/a[5]
SILICA SAND					
Shaw Resources (a member of the Shaw Group Limited)	Nine Mile River, Hants County	65,787	59 682	7	
Total (silica sand)		65,787	59 682	7	*
DIMENSION STONE					
Scotia Slate Products Ltd	Rawdon Hills, Hants County	n/a	n/a	17	
Wallace Quarries Ltd	Quarry: Wallace, (Sandstone) Cumberland County	541	491	8	
Total (dimension stone)		541	491	25	*
PEAT MOSS					
Annapolis Valley Peat Moss Company[3]	Berwick, Kings County	1,760	1 597	29	
McDonald Peat Moss Limited[3]	Kennetcook, Hants County	1,294	1 174	30	
Total (peat moss)		3,054	2 771	59	*
AGGREGATES					
Crushed Stone	Various	9,630,618	8 736 839	234	58,811,000
Sand and Gravel	Various	3,261,706	2 959 000	114	14,096,000
Total (aggregates)		12,892,324	11 695 839	348	72,907,000
TOTAL FOR INDUSTRIAL MINERALS[4]		22,530,285	20,439,340	1267	208,742,000

* value not shown, but included in total
[1]total employees: mining, production, clerical, supervisory, etc
[2]estimate from Nova Scotia Department of Natural Resources sources
[3]processed or manufactured value
[4]does not include the value of Lafarge Canada Inc. production, which value is included in the higher manufactured value (cement)
[5]value included in the higher manufactured valuation (bricks)
[6]excluding secondary mineral manufacturing (Table 1.5)
Note: production represents shipments, numbers may not add to totals due to rounding

a short period in January and part of February, during which time the company's coal sales contract was negotiated and renewed, and during a summer shutdown period in July and August.

The coal mined from the Stellarton operation is blended on-site with coal trucked from the Coalburn Mine before being shipped to Nova Scotia Power Inc. (NSPI) generating stations.

THORBURN MINING LIMITED

Manager: C. Chisholm
Address: P. O. Box 1328
Antigonish, N. S. B2G 2L7
Production: 68,012 tons (61 700 tonnes) of coal
Employees: 18

The Coalburn surface coal mine is located in Coalburn, Pictou County. The mine began operations in June 1999, and extracts coal from both the Upper and Lower MacKay seams. The seams are approximately 0.9 metres in thickness. In 2000, the operator obtained revised permits to employ blasting and to use a highwall miner at the property. The highwall miner is a remotely controlled system that extracts coal in a series of headings driven from the coal seam face in a surface cut.

The company used the highwall mining method to extract coal from both seams during 2001. Conventional surface mining methods were used to mine additional coal and establish coal faces for the highwall miner. Conventional surface mining at Coalburn employs blasting to break the overlying rock and the material is loaded and hauled using hydraulic excavators and off road haul trucks.

Production from the Coalburn Mine is trucked to Pioneer Coal's facility in Stellarton for blending with other coals, and subsequently supplied to NSPI.

CAPE CRUSHING COMPANY LIMITED

Manager: E. Brogan
Address: P. O. Box 265
North Sydney, N. S. B2A 3M3
Production: 23,354 tons (21 187 tonnes) of coal
Employees: 10

The company operates a small surface coal mine at Alder Point, Cape Breton County, to supply the local domestic market and NSPI. The mine extracts coal from the Lloyd Cove (Bonar) Seam. Mining is carried out using mechanical equipment to break the coal and overlying rock.

BROGAN MINING COMPANY LIMITED

Manager: R. Brogan
Address: 638 Bras d'Or Road
Florence, N. S. B1Y 1E4
Production: 53,991 tons (48 980 tonnes) of coal
Employees: 20

During the year, Brogan Mining Company Limited operated a surface coal mine at Little Pond, Cape Breton County. Coal is recovered from the Lloyd Cove (Bonar) coal seam. The overlying waste rock and coal are broken mechanically and mining is carried out using bulldozers, hydraulic excavators and dump trucks. The coal production is marketed to NSPI.

The company also continued reclamation work at its mine site at Toronto Road, Cape Breton County, during 2001.

HILL RECLAMATION LTD.

Manager: M. McCormick
Address: R. R. #1
Springhill, N. S. B0M 1X0
Production: 8,547 tons (7 754 tonnes) of coal
Employees: 6

Hill Reclamation operates a rail bed coal recovery project near Springhill, Cumberland County. The company recovers coal from an abandoned railway bed and markets the coal to NSPI.

Industrial Minerals Mining

Gypsum and Anhydrite

FUNDY GYPSUM COMPANY

Manager: K. Hillman
Address: P. O. Box 400
Windsor, N. S. B0N 2T0
Production: 33,694 tons (30 567 tonnes) of anhydrite
1,729,580 tons (1 569 065 tonnes) of gypsum
Employees: 188

The Fundy Gypsum Company operates quarries and crushing plants in the Wentworth Road and Miller Creek areas near Windsor, Hants County. In 2001, the company produced gypsum from its Miller Creek quarry and both gypsum and anhydrite from the Wentworth quarry. The Wentworth ore is processed in the company's heavy media plant to separate the anhydrite and the gypsum.

The gypsum and anhydrite are transported by unit train to ship-loading facilities at Hantsport, a distance of 19 km. These products are shipped to wallboard and cement plants in the United States and Canada.

GEORGIA-PACIFIC CANADA, INC.

Manager: J. T. Kennedy
Address: P. O. Box 400
Port Hawkesbury, N. S. B0E 2V0
Production: 1,492,984 tons (1 354 426 tonnes) of gypsum
Employees: 114

Georgia-Pacific Corporation operates a gypsum quarry at Sugar Camp, Inverness County and continued development of its gypsum quarry at Melford, Inverness County during 2001.

Overburden at Sugar Camp is removed using trucks and shovels. The gypsum is drilled, blasted and transported to the crusher by trucks. Most of the quarry's production is transported by highway trucks to ship loading facilities at Point Tupper, Richmond County, a distance of 19 km. Georgia-Pacific also supplies gypsum to the wallboard plant at Point Tupper.

LITTLE NARROWS GYPSUM COMPANY

Manager: M. W. Bishop
Address: R. R. #1
Little Narrows, N. S. B0E 1T0
Production: 49,809 tons (45 186 tonnes) of anhydrite
1,039,566 tons (943 088 tonnes) of gypsum
Employees: 87

Little Narrows Gypsum Company operates a gypsum quarry and an anhydrite quarry near Little Narrows, Victoria County. The gypsum and anhydrite are drilled, blasted and loaded onto trucks with loaders and hydraulic excavators. All the gypsum and anhydrite produced is shipped from the company's dock on the Bras d'Or Lakes to destinations in Canada and the United States.

NATIONAL GYPSUM (CANADA) LTD.

Manager: P. C. Mills
Address: P. O. Box 57
Milford Station, N. S. B0N 1Y0
Production: 3,281,296 tons (2 976 772 tonnes) of gypsum
Employees: 100

National Gypsum (Canada) Ltd. operates the largest gypsum quarry in the province at East Milford, Halifax County. The gypsum is drilled, blasted and loaded onto trucks with loaders and hydraulic excavators. The gypsum is crushed, screened, and transported by unit train from Milford to Wright's Cove, Dartmouth, a distance of 45 km, where it is loaded onto ships for points in Canada and the United States.

TUSKET MINING INC.

Manager: C. E. Bain
Address: P. O. Box 48100
Bedford, N. S. B4A 3Z2
Production: 0 tons (0 tonnes)

Table 1.5. Secondary mineral manufacturing for the calendar year 2001.

COMPANY	LOCATION	PRODUCTION		TOTAL NUMBER EMPLOYED[1]	APPROX. VALUE ($)[2]
		TONS	TONNES		
CLAY PRODUCTS					
Shaw Brick (a member of the Shaw Group Limited)	Lantz, Hants County	35,936	32 601	48	*
PORTLAND CEMENT					
Lafarge Canada Inc.	Brookfield, Colchester County	322,434	292 510	52	*
TOTAL FOR SECONDARY MINERAL MANUFACTURING				100	39,306,000

* value not shown, but included in total
[1]total number of employees including office, clerical, supervisory, mining and production
[2]estimated from Nova Scotia Department of Natural Resources sources
NOTE: Production represents shipments; numbers may not add to totals due to rounding

There was no activity at the Murchyville Mine, Halifax County, during the year. The site remains on a care and maintenance basis while markets for the gypsum are found.

Salt

THE CANADIAN SALT COMPANY LIMITED

Manager: A. W. Davidson
Address: P. O. Box 160
Pugwash, N. S. B0K 1L0
Production: 1,124,484 tons (1 020 125 tonnes) of salt
Employees: 218

The Canadian Salt Company Limited operates an underground salt mine at Pugwash, Cumberland County. The salt is mined by a room and pillar system of extraction, using diesel/electric drills, undercutters, loaders and trucks. Production during the year was from the 1000 and 830 levels.

The processing plant at the site produces a wide range of salt products, including industrial grades of salt, salt blocks for farm use, and refined salt for domestic consumption. Transportation is by road, rail or from the company owned ship-loading facility at Pugwash.

SIFTO CANADA INCORPORATED

Manager: D. E. Dickie
Address: P. O. Box 550
Amherst, N. S. B4H 4A1
Production: 94,446 tons (85 681 tonnes) of salt
Employees: 49

Salt has been produced from the solution salt mine at Nappan, Cumberland County, since 1947. Salt is mined by solution mining where water is pumped in underground wells and the salt is dissolved. The resulting brine solution is then returned to the surface. The salt is recovered from the brine in a processing plant, using a 'mechanical vapour recompression evaporating process' system. The plant produces a wide range of refined salt products.

During the year, two new brine wells were drilled and placed under development, the Nos. 9 and 10 wells. Salt was produced from the Nos. 6, 7, 8, 9, and 10 brine wells.

Barite

E-Z-EM CANADA, INC., NYSTONE DIVISION

Manager: V. J. Prostak
Address: P. O. Box 69
Debert, N. S. B0M 1G0
Production: 5,000 tons (4 536 tonnes) of barite
Employees: 16

E-Z-EM Canada's barite deposit is located 1.6 km northeast of Brookfield, Colchester County. During 2001, approximately 4536 tonnes of ore were produced from the surface mine. The ore was trucked to the company's plant at Debert where it

Table 1.6. Metallic mineral production for the calendar year 2001.

COMPANY	LOCATION	PRODUCTION		TOTAL NUMBER EMPLOYED	APPROX. VALUE($)[2]
		TROY OZ.	g		
GOLD					
Dufferin Resources Inc.[1]	Port Dufferin, Halifax County	7,287	226 600	33	3,088,000
TOTAL FOR METALLIC MINERAL PRODUCTION					3,088,000

[1]operated for part of year only
[2]value based on average annual metal price

was upgraded to a pharmaceutical quality product. The refined product is shipped to the parent company, E-Z-EM Corporation, New York, USA, for further processing and packaging.

Limestone and Dolomite

LAFARGE CANADA INC.

Manager: L. MacArthur
Address: P. O. Box 5
Brookfield, N. S. B0N 1C0
Production: 496,823 tons (450 715 tonnes) of limestone
Employees: 20 (quarry) 52 (cement plant)

Lafarge Canada Inc. operates a limestone quarry near its Brookfield cement plant, 5 km west of Brookfield, Colchester County. The total production from the quarry is used at the cement plant.

MOSHER LIMESTONE COMPANY LIMITED

Manager: D. M. Mosher
Address: P. O. Box 28
Upper Musquodoboit, N. S. B0N 2M0
Production: 35,374 tons (32 091 tonnes) of dolomite/limestone
Employees: 23

Mosher Limestone operates a number of quarries near Upper Musquodoboit, Halifax County. The company produces agricultural grade dolomite/limestone in its grinding plant at Upper Musquodoboit. The product is bagged or supplied in bulk for distribution throughout the Atlantic Provinces. The company also produces a pelletized limestone product for the domestic garden market.

NOVA SCOTIA POWER INCORPORATED (OPERATED BY KELLY ROCK LIMITED)

Manager: D. W. MacKenna (Kelly Rock Limited)
Address: P. O. Box 1206
Sydney, N. S. B1P 6J9
Production: 131,950 tons (119 704 tonnes) of limestone
Employees: 10

The limestone quarry at Glen Morrison, Cape Breton County, began production in 1993. The company produces several products at the on-site milling facility. During 2001, most of the production from this site was shipped to Point Aconi for use in the fluidized bed power generating station. Kelly Rock Limited operates the quarry on behalf of Nova Scotia Power.

RIDGE BROKERS LIMITED

Manager: E. Alward
Address: P. O. Box 2001
Havelock, N. B. E4Z 6H3
Production: 11,023 tons (10 000 tonnes) of limestone
Employees: 1

The company operates a small quarry at Southside Antigonish Harbour, Antigonish County, producing limestone for the agricultural market.

SCOTIA LIMESTONE LIMITED

Manager: D. M. Mosher
Address: P. O. Box 28
Upper Musquodoboit, N. S. B0N 2M0
Production: 6,614 tons (6 000 tonnes) of dolomite
Employees: 2

The Kelly's Cove dolomite quarry and plant operation is located near New Campbellton, Victoria County. The plant produces an agricultural grade dolomite for domestic sale, a ground dolomite product for coal mine stone dust, and dolomite products for the offshore steel industry. All 2001 production came from the existing ore inventory and no mining took place at the site during 2001.

Clay

SHAW BRICK, A MEMBER OF THE SHAW GROUP LIMITED

Manager: B. Frizzell
Address: P. O. Box 2130
Lantz, N. S. B0N 1R0
Production: 35,936 tons (32 601 tonnes) of clay & shale

Shaw Brick extracts clay from pits at Lantz, Milford and Shubenacadie, all in Hants County, and shale from quarries located in Hardwood Lands, Hants County, and New Glasgow, Pictou County. These materials are used in the company's plant in Lantz for the manufacture of bricks and other structural clay products.

Silica Sand

SHAW RESOURCES, A MEMBER OF THE SHAW GROUP LIMITED

Manager: G. Dickie
Address: P. O. Box 60
Shubenacadie, N. S. B0N 2H0
Production: 65,787 tons (59 682 tonnes) of silica sand
Employees: 7

Shaw Resources produces silica sand from a deposit at West Indian Road, Hants County. This sand is processed into several silica sand products including glass-grade sand.

Dimension Stone

WALLACE QUARRIES LIMITED

Manager: S. Flynn
Address: P. O. Box 203
Wallace, N. S. B0K 1Y0
Production: 541 tons (491 tonnes) of building stone
Employees: 5

The Wallace Quarries, located near Wallace, Cumberland County, continued to supply building stone for major building rehabilitation work in Halifax and central Canada. Blocks of stone are sent for cutting to processing facilities in Nova Scotia, New Brunswick and Quebec to supply local markets.

Slate

SCOTIA SLATE PRODUCTS LTD.

President: D. Donovan
Address: Box 12, Comp 3,
Kennetcook, N. S. B0N 1P0
Employees: 17

The company produces a range of slate products from its quarry at Rawdon Hills, Hants County.

Peat Moss

ANNAPOLIS VALLEY PEAT MOSS COMPANY LIMITED

President: H. Endres
Address: Berwick, N. S. B0P 1E0
Production: 1,760 tons (1 597 tonnes) of peat moss
Employees: 29

The company uses vacuum harvesters to recover agricultural peat from a 200 ha bog located near Berwick, Kings County. Baled peat products are shipped to markets in Canada, the United States and Japan.

MACDONALD PEAT MOSS LIMITED

Owner: Lameque Quality Group Ltd.
Address 86 Tourbe Street
Lameque, N. B. E8T 1A3

Production: 1,294 tons (1 174 tonnes) of peat moss
Employees: 30

MacDonald Peat Moss Limited, a wholly-owned subsidiary of New Brunswick's Lameque Quality Group Ltd., has lease rights to a 688 ha peat bog located on Crown land, approximately 12 km west of Kennetcook, Hants County. The company began operations in 1999, exporting baled peat to international markets.

Aggregate Resources

Approximately 11.7 million tonnes of construction aggregates were produced in Nova Scotia in 2001. Twenty companies reported crushed stone production totaling 8.7 million tonnes while 30 producers reported sand and gravel production totaling 3 million tonnes. The majority of the aggregates were consumed within the province.

Two companies eclipsed the 1 million tonne mark for crushed stone production in 2001. Rocky Lake Quarry Limited of Bedford, Nova Scotia, reported shipments of 1.5 million tonnes and Martin Marietta Materials Canada Ltd. reported over 2.5 million tonnes shipped.

Appendix 2

Mineral Resources Branch
Geoscience Maps and Publications for Sale

Maps

Bedrock Geology Maps

Provincial Scale

1:2 000 000

Map ME 1979-6 Metamorphic Map of Nova Scotia, by J. D. Keppie and G. K. Muecke, 1979, scale 1:2 000 000. **FREE** (Map ME 2000-1 is the most recent provincial scale geology map of Nova Scotia).

Map ME 1979-4 Geological Map of Nova Scotia, by J. D. Keppie, 1979, scale 1:2 000 000. **FREE** (Map ME 2000-1 is the most recent provincial scale geology map of Nova Scotia).

1:500 000

Map ME 2000-1 Geological Map of the Province of Nova Scotia, by J. D. Keppie, 2000, scale 1:500 000. **$20.00**

Regional Scale

1:250 000

Map ME 1994-1 Geological Map of the South Mountain Batholith, Western Nova Scotia, by M. A. MacDonald with contributions from M. C. Corey, L. J. Ham and R. J. Horne, 1994, scale 1:250 000. **$6.00**

1:125 000

Map ME 1978-1 Preliminary Geology Map of the Cobequid Highlands, by H. V. Donohoe and P. I. Wallace, 1978, scale 1:125 000, (superseded by Map ME 1982-6, Map ME 1982-7, Map ME 1982-8, Map ME 1982-9, scale 1:50 000). **$3.50**

1:100 000

OFM ME 2001-1 Map of Bedrock Aggregate Potential in the Halifax-Dartmouth Metropolitan Area Nova Scotia, by G. Prime, 2001, scale 1:100 000. [accompanies Economic Geology Series ME 2001-1.] **$5.00**

OFM ME 1998-1 Preliminary Geological Map of Guysborough, Richmond and Antigonish Counties (parts of NTS sheets 11E/08, 11F/05, 11F/06, 11F/10, 11F/11, 11F/12 and 11F/15, Nova Scotia, Canada, by C. E. White and S. M. Barr, 1998, scale 1:100 000. **$5.00**

Map ME 1984-2 Geological Map of the Boisdale Peninsula, Central Cape Breton Island, Cape Breton County, Nova Scotia, by S. M. Barr and J. R. D. Setter, 1984, scale 1:100 000. **$4.00**

Detailed Scale

1:50 000

Map ME 2001-1 Geological Map of the Meguma Group in the Rawdon Area [part of 11E/04], Hants County, Nova Scotia, by R. J. Horne, L. A. MacDonald, M. S. King, 2001, scale 1:50 000. **$5.00**

OFM ME 2000-3 Preliminary Geological Map of the Wolfville/Windsor Area, Hants and Kings Counties, Nova Scotia [21H/01 and Parts of 21A/16C and D], by R. G. Moore, S. A. Ferguson, R. C. Boehner, C. M. Kennedy, 2000, scale 1:50 000. **$5.00**

OFM ME 1999-3 Geological Map of the Musquodoboit Batholith, Halifax County [part of NTS sheet 11D/15], Nova Scotia, by L. J. Ham, 1999, scale 1:50 000. **$5.00**

OFM ME 1999-2 Geological Map of the Musquodoboit Batholith, Halifax County [part of NTS sheet 11D/14], Nova Scotia, by L. J. Ham, 1999, scale 1:50 000. **$5.00**

Map ME 1996-1 Geological Map of the Shubenacadie and Musquodoboit Basins Showing the Extent of Early Cretaceous Sediments (part of NTS Map Sheet 11E/03), Colchester and Halifax Counties, Nova Scotia, by R. R. Stea, P. W. Finck, S. E. Pullan, and M. C. Corey, 1996, scale 1:50 000. **$6.00**

Map ME 1994-8 Geological Map of Bridgetown, Nova Scotia (NTS Sheet 21A/14), by M. A. MacDonald and L. J. Ham, 1994, scale 1:50 000. **$6.00**

Map ME 1994-7 Geological Map of Digby, Nova Scotia (NTS Sheet 21A/12), by L. J. Ham, 1994, scale 1:50 000. **$6.00**

Map ME 1994-6 Geological Map of Milford, Nova Scotia (NTS Sheet 21A/11), by M. C. Corey and R. J. Horne, 1994, scale 1:50 000. **$6.00**

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Map ME 1992-1 Geological Map of Gaspereau Lake (NTS Sheet 21A/15 and part of 21H/02), Nova Scotia, by M. A. MacDonald and L. J. Ham, 1992, scale 1:50 000. **$6.00**

Map ME 1990-14 Cumberland Basin Geology Map, Tatamagouche and Malagash, Cumberland, Colchester and Pictou Counties, by R. J. Ryan and R. C. Boehner, 1990, scale 1:50 000. **$6.00**

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Map ME 1982-8 Geological Map of the Cobequid Highlands, Colchester, Cumberland and Pictou Counties, Nova Scotia, Economy River - Folly Lake Region, Sheet 3 of 4, by H. V. Donohoe, Jr., and P. I. Wallace, 1982, scale 1:50 000. **$8.00. $25.00 for set of Map ME 1982-6 to Map ME 1982-9.**

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Map ME 1982-2 Geological Map of the Antigonish Basin, by R. C. Boehner and P. S. Giles, 1982, scale 1:50 000. **$3.00**

1:31 680

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Map ME 1967-1 Geology, Crowdis Mountain Area, Victoria County, Nova Scotia, by G. C. Milligan, R. C. Parsons, B. White, R. M. Creed and A. K. Chatterjee, 1967, scale 1:31 680 (accompanies Memoir ME 7). **$3.00**

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1:25 000

Map ME 1997-1 Geological Map of a Portion of the South-Central Cape Breton Highlands (part of

NTS map sheet 11K/07), Victoria and Inverness Counties, Nova Scotia, by L. J. Ham, 1997, scale 1:25 000. (accompanies Paper ME 1997-1). **$6.00**

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OFM ME 1988-43 Preliminary Geological Maps of the Cumberland Basin, Amherst (21H/16), by R. C. Boehner, R. J. Ryan and A. Deal, 1988, 11 maps, scale 1:10 000. **$2.00 each**

OFM ME 1988-42 Preliminary Geological Maps of the Cumberland Basin, Springhill and Apple River (21H/09 and 21H/10), by R. J. Ryan, A. Deal, J. H. Calder and R. C. Boehner, 1988, 24 maps, scale 1:10 000. **$2.00 each**

OFM ME 1988-41 Preliminary Geological Maps of the Cumberland Basin, Cape Chignecto and Parrsboro (21H/07 and 21H/08), by A. Deal, R. J. Ryan and R. C. Boehner, 1988, 13 maps, scale 1:10 000. **$2.00 each**

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Glacial/Surificial Geological Maps

Provincial Scale

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1:100 000

Map ME 1990-6 Surficial Geology Map of Parts of Halifax, Pictou, Antigonish and Guysborough Counties (Sheet 12), Map Sheets 11E/09, 10, 15, 16 and parts of 11E/07 and 11E/08, by R. R. Stea and R. A. Myers, 1990, scale 1:100 000. **$13.00**

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Map ME 1979-014 Pleistocene geology map of the Eastern Shore Region, Halifax and Guysborough Counties, Nova Scotia [sheet 3 of 3] [11D/14, 11D/15 and 11E/02 and parts of 11D/11 and 11E/03], by R. R. Stea and J. H. Fowler, 1979, scale 1:100 000. **$4.00**

Map ME 1979-013 Pleistocene geology map of the Eastern Shore Region, Guysborough and Halifax Counties, Nova Scotia [sheet 2 of 3] [11E/01 and parts of 11E/02, 11E/07, 11E/08, 11E/11, 11F/04, 11F/05, 11C/13, 11D/15 and 11D/16, by R. R. Stea and J. H. Fowler, 1979, scale 1:100 000. **$4.00**

Map ME 1979-012 Pleistocene geology map of the Eastern Shore Region, Guysborough County, Nova Scotia [sheet 1 of 3] [11F/06 and parts of 11F/03, 11F/04, 11F/05, 11F/07, 11F/11 and 11F/12], by R. R. Stea and J. H. Fowler, 1979, scale 1:100 000. **$4.00**

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1:50 000

OFM ME 2003-1 Surficial Geology Map of the Whycocomagh Area (NTS 11F/14), Inverness County, Nova Scotia, by R. R. Stea and M. Feetham, 2003, scale 1:50 000. **$20.00**

OFM ME 1998-3 Surficial Geology of the Shubenacadie area (NTS 11E/03), Colchester, Halifax and Hants Counties, Nova Scotia, by R. R. Stea and C. M. Kennedy, 1998, scale 1:50 000. **$5.00**

OFM ME 1998-7 Surficial Geology of the Bridgetown area (NTS 21A/14), Annapolis County, Nova Scotia, by R. R. Stea and C. M. Kennedy, 1998, scale 1:50 000. **$5.00**

Map ME 1994-14 Glacial and Till Clast Geology Map of Gaspereau Lake, Nova Scotia (NTS Sheet 21A/15), by P. W. Finck, R. M. Graves, F. J. Boner and H. B. Bent, 1994, scale 1:50 000. **$6.00**

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Map ME 1994-12 Glacial and Till Clast Geology Map of Kejimkujik Lake, Nova Scotia (NTS Sheets 21A/06 plus part of 21A/07), by P. W. Finck, F. J. Boner and R. M. Graves, 1994, scale 1:50 000. **$6.00**

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Map ME 1993-2 Glacial and Till Clast Geology Map of New Germany (NTS Sheet 21A/10), Nova Scotia, by P. W. Finck, R. M. Graves and F. J. Boner, 1992, scale 1:50 000. **$6.00**

OFM ME 1991-5 to OFM ME 1991-18 Aggregate Potential of Cumberland and Colchester Counties (14 preliminary map sheets), (11E/02, 11E/03, 11E/05, 11E/06, 11E/07, 11E/11, 11E/12, 11E/13, 11E/14, 21H/07, 21H/08, 21H/09, 21H/10, 21H/16), by G. Prime, 1991, scale 1:50 000. **$2.00 per NTS Map Sheet**

Map ME 1990-4 Till Clast and Glacial Geology Map of Chester (21A/09), Nova Scotia, by R. M. Graves and P. W. Finck, 1990, scale 1:50 000. **$11.00**

OFM ME 1988-52 Preliminary Till Geochemistry and Till Clast Geology of the Windsor Map Sheet (21A/16), by F. J. Boner, P. W. Finck and R. M. Graves, 1988, scale 1:50 000. **$2.00**

OFM ME 1988-14 Glacial and Till Clast Geology of the Windsor Map Sheet (21A/16), by P. W. Finck, R. M. Graves, F. J. Boner and H. G. Bent, 1988, scale 1:50 000. **$2.00**

Map ME 1987-4 Till Clast and Simplified Glacial Geology Map of Halifax-Sambro (11D/12 and 11D/05), by R. M. Graves and P. W. Finck, 1987, scale 1:50 000. **$6.00**

Map ME 1987-3 Till Clast and Simplified Glacial Geology Map of Mount Uniacke (11D/13 West), by R. M. Graves and P. W. Finck, 1987, scale 1:50 000. **$6.00**

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Map ME 1987-1 Glacial Geology Map of Mount Uniacke (11D/13 West), by P. W. Finck and R. M. Graves, 1987, scale 1:50 000. **$6.00**

1:25 000

OFM ME 1992-2 Surficial Geology of the South-Central Cape Breton Highlands (11K/07), by P. W. Finck, 1992, scale 1:25 000. **$2.00**

Structure/Tectonic Maps

Provincial Scale

1:2 000 000

Map ME 1982-13 Lineament Map of Nova Scotia, by J. D. Keppie, 1982, scale 1:2 000 000. **FREE**

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Map ME 1979-5 Structural Map of Nova Scotia, by J. D. Keppie, 1979, scale 1:2 000 000. **FREE**

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Provincial Scale

1:2 000 000

Map ME 1979-7 Principal Classes of Mineral Deposits Map of Nova Scotia, by A. K. Chatterjee and J. D. Keppie, 1979, scale 1:2 000 000. **FREE**

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OFM ME 2000-6 Mineral Rights Disposition Map for Province of Nova Scotia, Version 8 (June 18, 2003), by B. E. Fisher, I. M. MacLellan, and A. S. Wenning, 2002, scale 1:500 000. **$5.00**

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Claim Reference Maps of Nova Scotia, undated, scale 1:31 680. **$1.00 per map**

Publications

Acts

Mineral Resources Act and Regulations, S.N.S. 1990, c. 18. **$9.35**

Gypsum Mining Income Tax Act, R.S.N.S. 1979, c. 190. **$1.00**

Treasure Trove Act, 1954. **FREE**

Annual Reports

The Department stopped publishing Annual Reports after the 1993/94 report. Copies of existing Annual Reports are available free upon request. The mineral and mining statistics normally published in the Annual Reports can now be found in the Mineral Resources Branch Report of Activities (under the **REPORTS** section).

Bulletins

Bulletin ME 7 Structure of the Canadian Appalachians, by J. D. Keppie, 1992, 89 pages, 3 maps, 3 figures in back pocket. **$8.00 (Microfiche $2.00)**

Bulletin ME 6 Evaluation of Nova Scotia's Peatland Resources, by A. R. Anderson and W. A. Broughm, 1988, 109 pages, 3 maps, scale 1:250 000. **$15.00**

Bulletin ME 5 Salt and Potash Resources in Nova Scotia, by R. C. Boehner, 1986, 346 pages, 8½" x 11" format, includes Map ME 1983-3, scale 1:500 000. **$17.00 (Microfiche $5.00)**

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Bulletin ME 2 (Part II) Limestones and Dolomites of Nova Scotia, Part II - Antigonish, Guysborough, Pictou, and Cumberland Counties, by D. A. Murray, 1975, 155 pages. **$6.50**

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Bulletin ME 1 Port Hawkesbury Project - Geology, Geochemistry and Groundwater Investigations of Southwest Inverness and Richmond Counties, Nova Scotia, by F. S. Shea and J. D. Wallace, 1962, 73 pages, 5 maps. **$2.00**

Contribution Series

CS ME 2003-001 Nitrogen Distribution in Lower Paleozoic Slates/Phyllites of the Meguma Supergroup, Nova Scotia, Canada: implications for Au and Zn-Pb Mineralization and Exploration, by U. A. Glasmacher, M. Zentilli and R. J. Ryan, 2003; *in* Chemical Geology, vol. 194, pages 297-329. **FREE**

CS ME 2002-6 Petrology, Age, and Tectonic Setting of the White Rock Formation, Meguma Terrane, Nova Scotia: evidence for Silurian Continental Rifting, by L. A. MacDonald, S. M. Barr, C. E. White, J. W. F. Ketchum, 2002; *in* Canadian Journal of Earth Sciences, vol. 39, pages 259-277. **FREE**

CS ME 2002-5 Late-stage Crystallization History of the Jurassic North Mountain Basalt, Nova Scotia, Canada. 1. Textural and Chemical Evidence for Pervasive Development of Silicate-liquid Immiscibility, by D. J. Kontak, M. Y. De Wolfe De Young, J. Dostal, 2002; *in* Canadian Mineralogist, vol. 40, pages 1287-1311. **FREE**

CS ME 2002-4 A Petrological, Geochemical, Isotopic and Fluid-inclusion Study of 370 Ma Pegmatite-aplite Sheets, Peggys Cove, Nova Scotia, Canada, by D. J. Kontak, J. Dostal, T. K. Kyser, D. A. Archibald, 2002; *in* Canadian Mineralogist, vol. 40, pages 1249-1286. **FREE**

CS ME 2002-3 Ice Etchings, by R. R. Stea, G. A. O'Reilly, 2002; *in* Canadian Chemical News, vol. 54, pages 29-30. **FREE**

CS ME 2002-2 Ar^{40}/Ar^{39} Dating of Hydrothermal Biotite from High-grade Gold Ore, Tangier Gold Deposit, Nova Scotia: Further Evidence for 370 Ma Gold Metallogeny in the Meguma Terrane, by D. J. Kontak, D. A. Archibald, 2002; *in* Economic Geology, vol. 97, pages 619-628. **FREE**

CS ME 2002-1 Fires Sweep Across the Mid-Cretaceous Landscape of Nova Scotia, by A. C. Scott, R. R Stea, 2002; *in* Geoscientist, vol. 12, pages 4-6. **FREE**

CS ME 2001-7 The Nature and Origin of Pegmatites in a Fluorine-rich Leucogranite, East Kemptville Tin Deposit, Nova Scotia, Canada, by D. J. Kontak, K. Ansdell, J. Dostal, W. Halter, R. Martin, A. E. Williams-Jones, 2001; *in* Royal Society of Edinburgh Transactions: Earth Sciences, vol. 92, pages 173-200. **FREE**

CS ME 2001-6 An Evolutionary Model of Glacial Dispersal and Till Genesis in Martime Canada, by R. R. Stea, P. W. Finck, 2001; *in* Drift Exploration in Glaciated Terrain, Geological Society Special Publication 185, pages 237-265. **FREE**

CS ME 2001-5 Glaciation and Relative Sea-Level Changes in Maritime Canada, by R. R. Stea, G. B. J. Fader, D. B. Scott, P. Wu, 2001; *in* Deglaciation History and Relative Sea-Level Changes, Northern New England and Adjacent Canada, Geological Society of America Special Paper 351, pages 35-49. **FREE**

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CS ME 2000-3 Granite-hosted Mineral Deposits of the New Ross Area, South Mountain Batholith, Nova Scotia, Canada: P, T and X Constraints of Fluids using Fluid Inclusion Thermometry and Decrepitate Analysis, by S. Carruzzo, D. J. Kontak, D. B. Clarke, 2000; *in* Royal Society of Edinburgh Transactions: Earth Sciences, vol. 19, pages 303-319. **FREE**

CS ME 2000-2 Zn-Pb Mineralization Associated with a Mafic Dyke at Cheverie, Hants County, Nova Scotia: Implications for Carboniferous Metallogeny, by D. J. Kontak, K. Ansdell, D. A.

Archibald, 2000; *in* Atlantic Geology, vol. 36, pages 7-26. **FREE**

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CS ME 1999-6 A Late Neoproterozoic Age for a Tonalite Dyke in the Boisdale Hills, Cape Breton Island, Nova Scotia, by S. M. Barr, S. Kamo, C. E. White, 1999; *in* Atlantic Geology, vol. 35, pages 197-202. **FREE**

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CS ME 1999-4 New Constraints on the Age and Origin of the Dunbrack Pb-Cu-Zn-Ag Deposit, Musquodoboit Batholith, Southern Nova Scotia, by D. J. Kontak, K. Ansdell, D. A. Archibald, 1999; *in* Atlantic Geology, vol. 35 (1999), pages 19-42, 3 maps. **FREE**

CS ME 1999-3 Using Whole Rock Geochemistry to Locate the Source of Igneous Erratics from Drumlins on the Atlantic Coast of Nova Scotia, by R. R. Stea, Nova Scotia Department of Natural Resources, Georgia Pe-Piper, Saint Mary's University, 1999; *in* Boreas, vol. 28, pages 308-325, 7 maps. **FREE**

CS ME 1999-2 Quartz Vein Styles in Turbidite-Hosted Mesothermal Gold Deposits of Western South Island (New Zealand), Victoria (Australia) and Nova Scotia (Canada), by A. B. Christie, P. K. Smith, R. J. Ryan, W. H. Ramsay, D. C. Arne, F. P. Bierlein; *in* The Australasian Institute of Mining and Metallurgy, 32nd Annual Conference, September 1999, pages 85-108. **FREE**

CS ME 1999-1 Documentation of Variable Trace- and Rare-Earth-Element Abundances in Carbonates from Auriferous Quartz Veins in Meguma Lode-Gold Deposits, Nova Scotia, by D. J. Kontak, S. J. Jackson; *in* Canadian Mineralogist, vol. 37, 1999, pages 469-488. **FREE**

CS ME 1998-17 Stratigraphy and tectonic significance of the Lower to Middle Devonian McAdams Lake Formation, Cape Breton Island, Nova Scotia, by C. E. White, Nova Scotia Department of Natural Resources, S. M. Barr, Acadia University; in Atlantic Geology, vol. 34, pages 133-145. **FREE**

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CS ME 1998-15 Origin and Evolution of the Greisenizing Fluid at the East Kemptville Tin Deposit, Nova Scotia, Canada, by W. E. Halter, Universite de Lausanne, A. E. Williams-Jones, McGill University, D. J. Kontak, Nova Scotia Department of Natural Resources; *in* Economic Geology, vol. 93, 1998, pages 1026-1051. **FREE**

CS ME 1998-14 The Carboniferous evolution of Nova Scotia, by J. H. Calder, Nova Scotia Department of Natural Resources; *in* Geological Survey of Canada, Special Publication 143, Lyell: the Past is the Key to the Present, eds. D. J. Blundell and A. C. Scott. **FREE**

CS ME 1998-13 $^{40}Ar/^{39}Ar$ Dating of Ribbon-Textured Veins and Wall-Rock Material from Meguma Lode Gold Deposits, Nova Scotia: Implications for Timing and Duration of Vein Formation in Slate-Belt Hosted Vein Gold Deposits, by D. J. Kontak, R. J. Horne, Nova Scotia Department of Natural Resources, H. Sandeman, D. A. Archibald, J. K. W. Lee, Queen's University; in Canadian Journal of Earth Science, 35 (1998), pages 746-761. **FREE**

CS ME 1998-12 Geology of the B Baseline Zone, Walton Cu-Pb-Zn-Ag-Ba Deposit, Nova Scotia, Canada, by D. F. Sangster, Geological Survey of Canada, M. D. Burtt, D. J. Kontak, Nova Scotia

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Memoir ME 10 Geology of the Cumberland Basin, Cumberland, Colchester and Pictou Counties, Nova Scotia, by R. J. Ryan and R. C. Boehner, 1994, 222 pages, 155 text figures and back pocket containing 5 pocket figures, and 4 coloured geology maps: Map ME 1990-11, Map ME 1990-12, Map ME 1990-13 and Map ME 1990-14. **$69.00 (Microfiche $6.00)**

Memoir ME 9 Geology of the Loch Lomond Basin and Glengarry Half Graben, Richmond and Cape Breton Counties, Cape Breton Island, Nova Scotia, by R. C. Boehner and G. Prime, 1993, 68 pages, 1 map. (Includes Map ME 1985-2, Geology of the Loch Lomond Basin and Glengarry Half Graben, Nova Scotia, scale 1:50 000). **$8.00 (Microfiche $2.00)**

Memoir ME 8 Geology of the Antigonish Basin, Antigonish County, Nova Scotia, by R. C. Boehner and P. S. Giles, 1993, 132 pages. **$10.00 (Microfiche $3.00)**

Memoir ME 7 The Geology of the George River Series, Cape Breton, Stratigraphy, Structure and Economic Geology, by G. C. Milligan, 1970, 111 photocopied pages, 5 coloured and 2 black/white maps in back pocket: Map ME 1962-1, Map ME 1963-1, Map ME 1963-2, Map ME 1967-1, Map ME 1967-2 and Map ME 1967-3. **$10.00. (Microfiche $3.00)**

Memoir ME 5 Pleistocene Geology of the Annapolis Valley, Nova Scotia, by C. F. Hickox, 1962, 36 pages, 1 map. **$2.00**

Memoir ME 4 The Older Paleozoic of Pictou County, Nova Scotia, by R. H. Maehl, 1961, 109 pages, 1 appendix, 1 map. **$3.00**

Memoir ME 3 The Stratigraphy of the Windsor Group in the Antigonish Quadrangles and the Mahone Bay - St. Margaret's Bay Area, Nova Scotia, by N. M. Sage, Jr., 1954, 168 pages. **Out of Print (Microfiche only $2.00)**

Memoir ME 2 Stratigraphy and Paleontology of the Windsor Group (Upper Mississippian) in parts of Cape Breton Island, Nova Scotia, by M. C. Stacy, 1953, 143 pages. **Out of Print (Microfiche only $3.00)**

Memoir ME 1 Gypsum and Anhydrite in Nova Scotia, by N. R. Goodman, 1952, 75 pages. **Out of Print (Microfiche only $2.00)**

Miscellaneous Publications

MP ME 1975-3 Core Drilling in Nova Scotia with Government Drills, 1967-1971, 49 pages. **$1.00**

MP ME 1975-2 Drilling Logs of Government Core Drills, 1973, by I. MacDougall and D. W. Grimm, 76 pages. **$1.00**

MP ME 1975-1 Drilling Logs of Government Core Drills, 1972, by I. MacDougall and D. W. Grimm, 85 pages. **$1.00**

NOTE: Drilling logs after 1973 are published as part of the Report Series; e.g. Drilling Logs for 1974 are in **Report ME 1976-1**.

MP ME 1972-4 Geology of the Middle River and Baddeck Forks Map Areas, Victoria County, Nova Scotia, by B. E. Jones and T. G. N. Covert, 1972, 124 pages, 5 maps. **$5.00**

MP ME 1972-3 Clay and Sand Deposit at Elmsvale, Halifax County, Nova Scotia, by J. H. Fowler, 1972, 62 pages, drillhole sections. **Out of Print (Microfiche Only $2.00)**

MP ME 1972-1 Drilling Logs of Government Core Drills, 1971, by C. F. Townsend and D. W. Grimm, 81 pages. **$1.00**

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MP ME 1970-1 Drilling Logs of Government Core Drills, 1969, by C. F. Townsend and D. W. Grimm, 65 pages. **$1.00**

MP ME 1969-2 Handbook for Companies Planning Offshore Drilling, by Nova Scotia Department of Mines, 1969, 23 pages. **$0.50**

MP ME 1969-1 Drilling Logs of Government Core Drills, 1968 by C. F. Townsend and D. W. Grimm, 58 pages. **$1.00**

MP ME 1968-2 Core Drilling in Nova Scotia with Government Drills, 1871-1966, 176 pages. **$2.00**

MP ME 1968-1 Drilling Logs of Government Core Drills, 1967, by C. F. Townsend and D. W. Grimm, 39 pages. **$1.00**

MP ME 1967-1 Drilling Logs of Government Core Drills, 1966, by C. F. Townsend and D. W. Grimm, 27 pages. **$1.00**

MP ME 1966-3 Metallic Mineral Occurrences Recorded in the Province of Nova Scotia, by Nova Scotia Department of Mines, 1966, 350 pages. **$4.00**

MP ME 1966-1 Drilling Logs of Government Core Drills, 1965, by C. F. Townsend and D. W. Grimm, 55 pages. **$1.00**

MP ME 1965-1 Drilling Logs of Government Core Drills, 1964, by C. F. Townsend and D. W. Grimm, 43 pages. **$1.00**

MP ME 1964-1 Drilling Logs of Government Core Drills, 1963, by C. F. Townsend and D. W. Grimm, 36 pages. **$1.00**

MP ME 1963-1 Drilling Logs of Government Core Drills, 1962, by C. F. Townsend and D. M. MacLeod, 35 pages. **$1.00**

MP ME 1962-1 Drilling Logs of Government Core Drills, 1961, by C. F. Townsend and D. M. MacLeod, 49 pages. **$1.00**

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MP ME 1959-1 Drilling Logs of Government Core Drills, 1958, by M. G. Goudge and D. M. MacLeod, 34 pages. **$1.00**

MP ME 1958-2 Possibilities for Occurrence of Petroleum Reservoirs in Nova Scotia, by W. A. Bell, 1958, 177 pages. **$1.00**

NOTE: Drilling Logs of Government Core Drills prior to 1958 are in Nova Scotia Department of Mines Annual Reports.

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OFR ME 2003-1 Selected Economic Mineral Deposits of the Walton Belt, Hants County, Nova Scotia: A Field Trip Guide, by R. F. Mills, G. A. O'Reilly and H. V. Donohoe, Jr., 2003, 39 pages. **$5.00**

OFR ME 2001-2 Geology of the South Mountain Batholith, Southwestern Nova Scotia, by M. A. MacDonald, 2001, 359 pages, 1 map (includes Map ME 1994-1). **$15.00**

OFR ME 2001-1 Fault-controlled Zinc Mineralization in the Antigonish Highlands, Antigonish and Pictou Counties, Nova Scotia, by G. A. O'Reilly, 2001, 9 pages, 6 coloured figures. **$5.00**

OFR ME 2000-3 Limestones and Dolomites of Nova Scotia, Part III, Colchester and Halifax Counties, Nova Scotia, by D. A. Murray, 2000, 181 pages, 28 maps. [For Part I, Cape Breton Island, see Bulletin ME 2, Part I; for Part II, Antigonish, Guysborough, Pictou and Cumberland Counties, see Bulletin ME 2, Part II.] **$15.00**

OFR ME 2000-1 NTS Location, Author and Citation Index to Nova Scotia Department of Natural Resources, Minerals and Energy Branch Assessment Reports, 1996-1999, by P. D. McCulloch, S. Marshall, N. A. Lyttle and J. S. Saunders, 2000, 116 pages. **$10.00**

OFR ME 1998-5 Classic Carboniferous Sections of the Minas and Cumberland Basins in Nova Scotia: with Special Reference to Organic Deposits, by J. H. Calder, R. C. Boehner, D. E. Brown, M. R. Gibling, P. K. Mukhopadhyay, R. J. Ryan and D. M. Skilliter; The Society for Organic Petrology, Annual Meeting Field Trip Guide Book, 29-30 July, 1998, 86 pages. **$10.00**

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OFR ME 1996-5 Geology of the Foord Seam and Associated Strata in the Area of the Stellarton Pit Mine, Pictou Coalfield, Stellarton Basin, Nova Scotia, by K. S. Gillis, R. D. Naylor and J. W. F. Waldron, 1996, 23 pages, 1 geology Map, scale 1:5000, 3 figures. **$15.00**

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OFR ME 1990-6 Trace Element Analysis of Till (-230 Mesh), South Mountain Batholith, (11D/05, 11D/12, 11D/13, 20P/13, 21A/03, 21A/04, 21A/05, 21A/06, 21A/07, 21A/09, 21A/10, 21A/11, 21A/12, 21A/14, 21A/15, 21A/16, 21H/02), by F. J. Boner, P. W. Finck and R. M. Graves, 1990, 40 pages, 1 map, scale 1:250 000. **$6.00**

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OFR ME 1989-7 Geochemical Analyses of Bulk Stream Sediment Samples from Northern Nova Scotia, by R. F. Mills, 1989, includes many tables and 3 sample location maps, scale 1:250 000. **$40.00**

OFR ME 1989-6 Summary Report on Quarry Stone Used in the Construction of Dominion Building, Halifax, N. S., by G. B. Dickie, 1989, 16 pages. **$3.00**

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OFR ME 1989-3 Open File Report on Selected Mineral Occurrences of the Antigonish Area, (NTS 11E/08, 11E/09 and 11E/16), by K. E. Northcote, G. DeMont and A. Armitage, February 1989, 184 pages, tables. **$15.00**

OFR ME 1989-1 Lithogeochemistry of the Eastern Portion of the South Mountain Batholith, Nova Scotia, (Map Sheets 11D/05, 11D/12, 11D/13, 21A/09, 21A/10, 21A/15, 21A/16, and parts of 21H/01 and 21H/02), by L. J. Ham, S. W. Marsh, M. C. Corey, R. J. Horne and M. A. MacDonald, 62 pages, 2 maps. **$15.00**

OFR ME 1988-63 An Assessment of the Hydrocarbon and Compressed Air Storage Potential of Nova Scotia: A Summary, by Nolan, Davis and Associates Ltd., 1988, 22 pages. **$3.00**

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OFR ME 1987-23 Report on the English Property (McKeen Quarry), Pictou County, by G. B. Dickie, 1987, 12 pages. **$5.00**

OFR ME 1987-5 Report on the Potential Stone Quarry, MacKenzie Farm, Hardwood Hill, Pictou County, Nova Scotia, by G. Dickie, 1986, 37 pages. **$5.00**

OFR ME 1987-2 Market Analysis for New Brunswick, Nova Scotia and Newfoundland Dimension Stone, by the DPA Group Incorporated in association with Jacques Whitford and Associates Limited, 1987, 66 pages. **$10.00**

OFR ME 1986-54 The U.K. Experience on the Effects of Offshore Sand and Gravel Extraction on Coastal Erosion and the Fishing Industry, by R. Warren Drinnan and Douglas G. Bliss, Dobrocky Sea Tech Limited, 1986, 90 pages. **$10.00**

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OFR ME 1986-25 The Gypsum Industry in Nova Scotia - Present Status and Future Prospects, by R. E. Wright and J. H. Brown, Centre for Resource Studies, Queen's University, 1985, 125 pages. **$15.00**

OFR ME 1986-13 Study of Markets for Silica and Silica Sands Accessible from Nova Scotia and New Brunswick, by ADI Limited, 244 pages. **$10.00**

OFR ME 1986-12 A Study of Industrial Minerals Used in Oil and Gas Exploration on the Eastern Canadian Offshore, by Jacques, Whitford and Associates, and Cleland, Dunsmuir Consulting Limited, 231 pages. **$17.00**

OFR ME 1986-10 Study of Markets for Aggregate Materials Accessible from Nova Scotia and New Brunswick, by ADI Limited, 1986, 398 pages. **$10.00**

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OFR ME 650 Guide to the Granites and Mineral Deposits of Southwestern Nova Scotia, edited by A. K. Chatterjee and D. B. Clarke, 1985, 264 pages. **$15.00**

OFR ME 648 Current Market Economics of the Strontium Minerals by Metals Economic Group, Nova Scotia, and Boulder, Colorado, 1985, 54 pages. **$5.00**

OFR ME 621 Effects of Location on Mine Development Potential: Nova Scotia's Competitive Position in Canada, by D. W. Davis, B. W. MacKenzie and M. L. Bilodeau, 1985, 103 pages. **$15.00**

OFR ME 605 Regional Lake Sediment Survey of the Meguma Zone, Southern Nova Scotia: New Analytical Data, by P. J. Rogers, M. A. MacDonald and D. W. Rigby, 1985, 65 pages, 2 maps. **$5.00**

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OFR ME 50 Carboniferous Stratigraphy and Economic Geology, Halifax, Hants and Colchester Counties, Nova Scotia; Canadian Institute of Mining and Metallurgy, Geology Division, Field Guide, by Mining Society of Nova Scotia, Atlantic Geoscience Society and Nova Scotia Department of Mines, 1974, 48 pages. **$1.00**

Outside Publications

OP ME 2003-1 Fundy Mineral Collecting, by I. Booth, 2003, 127 pages. (This guidebook describes fifty notable localities for collecting the Fundy zeolites and semi-precious minerals). **$20.00**

OP ME 2001-1 The Last Billion Years: A Geological History of the Maritime Provinces of Canada, by Atlantic Geoscience Society, 2001.

Atlantic Geoscience Society Special Publication No. 15. **$35.00**

OP ME 1998-2 A Special Issue Devoted to Lead-Zinc Mineralization and Basinal Brine Movement, Lower Windsor Group (Viséan), Nova Scotia, Canada; *in* Economic Geology and the Bulletin of the Society of Economic Geologists, v. 93, September-October 1998, no. 6, 260 pages. **$21.00**

OP ME 1998-1 Discovering Rocks, Minerals and Fossils in Atlantic Canada, A Geological Field Guide to Selected Sites in Newfoundland, Nova Scotia, Prince Edward Island, and New Brunswick, edited by P. Wallace, 1998, 186 pages; Atlantic Geoscience Society, Special Publication No. 14. **$25.00**

OP ME 1993-2 Zeolites of the Bay of Fundy, by I. Booth, 1993, 37 pages **$10.00**

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OP ME 1986-6 Occupational Safety in the Geosciences, Programme with Abstracts: A Seminar and Panel Discussion on Safety-Related and Legal Topics Concerning Geoscientists and Their Work Environments, Organized by the Atlantic Geoscience Society, and Co-Sponsored with the Department of Geology, Dalhousie University, The Nova Scotia Chamber of Mineral Resources, the Atlantic Provinces Council on the Sciences, and Geomarine Associates Limited; Dalhousie University, Halifax, Nova Scotia, September 25, 1985, Atlantic Geoscience Society, Special Publication Number 3, 100 pages. **$2.00**

OP ME 1986-5 Trip No. 14 Lithostratigraphic, Physical Diagenetic and Economic Aspects of the Pennsylvanian-Permian Transition Sequence of Prince Edward Island and Nova Scotia; H. W. van de Poll, J. R. DeGrace, R. J. Ryan, 1986; *in* Geological Association of Canada/Mineralogical Association of Canada Guidebooks for Field Excursions (Fredericton, May 15-17, 1985). **$7.00**

OP ME 1986-4 Trip No. 11 Turbidite-Hosted Gold Deposits, Meguma Domain, Eastern Nova Scotia; P. K. Smith, S. J. Haynes, B. E. Jones, 1986; *in* Geological Association of Canada/Mineralogical Association of Canada Guidebooks for Field Excursions (Fredericton, May 15-17, 1985), 67 pages. **$7.00**

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OP ME 1981-1 Malagash Salt, compiled and edited by J. R. MacQuarrie, c. 1975, 1981, 109 pages. **$5.00**

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D94-01. Geological Map of the South Mountain Batholith, Western Nova Scotia [parts of 11D and 21A], version 1, 1997, compiled by M. A. MacDonald, 1994, scale 1:250 000 (line work only, no point data)	E00 DXF/DBF	1.5 Mb 1.6 Mb	FREE DOWNLOAD
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D90-14. Cumberland Basin Geology Map Tatamagouche and Malagash, Cumberland, Colchester and Pictou Counties, Nova Scotia [11E/11 and 11E/14 south], version 1, 1997, compiled by R. J. Ryan and R. C. Boehner, 1990, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	400 Kb 458 Kb	FREE DOWNLOAD
D90-13. Cumberland Basin Geology Map Oxford and Pugwash, Cumberland County, Nova Scotia [11E/12 and 11E/13], version 1, 1997, compiled by R. J. Ryan and R. C. Boehner, 1990, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	600 Kb 763 Kb	FREE DOWNLOAD
D90-12. Cumberland Basin Geology Map Amherst, Springhill and Parrsboro, Cumberland County, Nova Scotia [21H/08, 21H/09 and 21H/10], version 1, 1997, compiled by R. J. Ryan, R. C. Boehner, A. J. Deal and J. H. Calder, 1990, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	500 Kb 600 Kb	FREE DOWNLOAD
D90-11. Cumberland Basin Geology Map, Apple River and Cape Chignecto, Cumberland County, Nova Scotia [21H/07 and 21H/10], version 1, 1997, compiled by R. J. Ryan and R. C. Boehner, 1990, 1:50 000 (line work only, no point data).	E00 DXF/DBF	300 Kb 408 Kb	FREE DOWNLOAD
D86-02. Geological Map of the Windsor Area, Nova Scotia [21A/16 north and 21H/01 south], version 1, 1997, compiled by R. G. Moore and S. A. Ferguson, 1986, 1:25 000 (line work only, no point data)	E00 DXF/DBF	864 Kb 832 Kb	FREE DOWNLOAD
D86-01. Geological Map of the Sydney Basin-Cape Breton, Nova Scotia [11K/01, 11K/08 and 11J/04], version 1, 1997, compiled by R. C. Boehner and P. S. Giles, 1986, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	1.2 Mb 1.6 Mb	FREE DOWNLOAD

MAPS (cont.).	FORMAT	SIZE/MEDIA	PRICE
D85-02. Geology of Loch Lomond Basin and Glengarry Half Graben, Nova Scotia [11F/15 east and 11F/16 west], version 1, 1997, compiled by R. C. Boehner and G. Prime, 1985, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	500 Kb 610 Kb	FREE DOWNLOAD
D85-01. Industrial Mineral Commodities Map of the Province of Nova Scotia, version 1, 1997, compiled by J. H. Fowler, 1985, scale 1:500 000.	E00 DXF/DBF	200 Kb 200 Kb	FREE DOWNLOAD
D84-02. Geological Map of the Boisdale Peninsula, Central Cape Breton Island, Cape Breton County, Nova Scotia [parts of 11F/15, 11F/16, 11K/01 and 11K/02], version 1, 1997, compiled by S. M. Barr and J. R. D. Setter, 1984, scale 1:100 000 (line work only, no point data)	E00 DXF/DBF	258 Kb 371 Kb	FREE DOWNLOAD
D83-05. Metallogenic Map of Nova Scotia, version 1, 1997, compiled by A. K. Chatterjee, 1983, scale 1:500 000 (includes the inset map **Metallogenic Associations and Domains of Silver,** scale 1:1 000 000).	E00 DXF/DBF	4 Mb 6 Mb	FREE DOWNLOAD
D83-01. Geological Map of the Hantsport Area, Nova Scotia [21H/01], version 1, 1997, compiled by S. A. Ferguson, 1983, scale 1:25 000 (line work only, no point data)	E00 DXF/DBF	459 Kb 609 Kb	FREE DOWNLOAD
D82-09. Geological Map of the Cobequid Highlands-Colchester, Cumberland and Pictou Counties, Nova Scotia, sheet 4 of 4 [11E/06, 11E/07 west and 11E/10 west], version 1, 1997, compiled by H. V. Donohoe Jr. and P. I. Wallace, 1982, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	600 Kb 649 Kb	FREE DOWNLOAD
D82-08. Geological Map of the Cobequid Highlands-Colchester, Cumberland and Pictou Counties, Nova Scotia, sheet 3 of 4 [11E/05 and 11E/12], version 1, 1997, compiled by H. V. Donohoe Jr. and P. I. Wallace, 1982, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	500 Kb 690 Kb	FREE DOWNLOAD
D82-07. Geological Map of the Cobequid Highlands-Colchester, Cumberland and Pictou Counties, Nova Scotia, sheet 2 of 4 [21H/08 and 21H/09], version 1, 1997, compiled by H. V. Donohoe Jr. and P. I. Wallace, 1982, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	600 Kb 650 Kb	FREE DOWNLOAD
D82-06. Geological Map of the Cobequid Highlands-Colchester, Cumberland and Pictou Counties, Nova Scotia, sheet 1 of 4 [21H/07], version 1, 1997, compiled by H. V. Donohoe Jr. and P. I. Wallace, 1982, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	400 Kb 391 Kb	FREE DOWNLOAD
D82-04. Geological Map of the Shubenacadie and Musquodoboit Basins, Central Nova Scotia [11D/13, 11D/14, 11E/02 west, 11E/04 east and 11E/03], version 1, 1997, compiled by P. S. Giles and R. C. Boehner, 1982, scale 1:50 000 (line work only, no point data)	E00 DXF.DBF	1 Mb 1.4 Mb	FREE DOWNLOAD

MAPS (cont.).	FORMAT	SIZE/MEDIA	PRICE
D82-03. Geological Map of the Eureka Area, Central Nova Scotia [11E/07D and 11E/10A], version 1, 1997, compiled by P. S. Giles, 1982, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	200 Kb 195 Kb	FREE DOWNLOAD
D82-02. Geological Map of the Antigonish Basin, Nova Scotia [parts of 11E/09, 11F/12 and 11F/13], version 1, 1997, compiled by R. C. Boehner and P. S. Giles, 1982, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	691 Kb 920 Kb	FREE DOWNLOAD
D79-03. Bouguer Gravity Anomaly Map of Nova Scotia, version 1, 1997, compiled by J. D. Keppie, 1979, scale 1:500 000.	E00 DXF/DBF	1 Mb 2 Mb	FREE DOWNLOAD
D79-01S. Structural Map of Nova Scotia, version 1, 1997, compiled by J. D. Keppie, 1979, scale 1:1 000 000 (insert from Map 79-1)	E00 DXF/DBF	1 Mb 1.5 Mb	FREE DOWNLOAD
D79-01M. Metamorphic Map of Nova Scotia, version 1, 1997, compiled by J. D. Keppie, 1979, scale 1:1 000 000 (insert from Map 79-1)	E00 DXF/DBF	700 Kb 1 Mb	FREE DOWNLOAD
D79-01. Geological Map of the Province of Nova Scotia, version 1, 1997, compiled by J. D. Keppie, 1979, scale 1:500 000 (does not include the 1:1 000 000 structural and metamorphic inset maps).	E00 DXF/DBF	5 Mb 6 Mb	FREE DOWNLOAD
D1752a. Geological map of northern Cape Breton Island, Nova Scotia [11K/02, 11K/03, 11K/06 to 11K/16, 11N/01, 11N/02] [1:100 000], version 1, 1997, compiled by S. M. Barr, R. A. Jamieson, R. P. Raeside, 1992, Geological Survey of Canada, Map 1752a.	E00 DXF/DBF	2 Mb 2 Mb	FREE DOWNLOAD
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DP 001b. Mineral occurrence database, version 7, May 2003. This database can be used with DP 001a, the Mineral Occurrence Query Program.	DBF	7 Mb	FREE DOWNLOAD
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DP 003. Drillholes database, version 2, 2000.	E00 DXF/DBF SHP	52 Mb 34 Mb 34 Mb	FREE DOWNLOAD
DP 004. Regional geochemical datasets (biogeochemical, lake and stream sediment, lake and stream water, soil, rock and till geochemical surveys), version 1, 1996.	E00 DXF/DBF	24 Mb 19 Mb	FREE DOWNLOAD

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DP 009. Claim reference map grid, Nova Scotia, version 2, 2000.	E00 DXF/DBF SHP	1.4 Mb 1.7 Mb 1.0 Mb	FREE DOWNLOAD
DP 010. Abandoned mine openings database, version 2, 2000.	E00 DXF/DBF SHP	7 Mb 3 Mb 3 Mb	FREE DOWNLOAD
DP 012. Claim, mining tract and petroleum reservations grids for claim reference maps, Nova Scotia, version 1, 2000	DXF/DBF SHP	3.6 Mb 3.9 Mb	FREE DOWNLOAD
IMAGES	**FORMAT**	**SIZE/MEDIA**	**PRICE**
DP 005. Airborne gamma ray spectrometric survey images, elemental and elemental ratio images covering 11D, 11E, 11F, 11G, 11J, 11K, 11N, 20O, 20P, 21A, 21B and 21H), version 1, 1997 (250 m x 250 m resolution).	TIFF	14 Mb	FREE DOWNLOAD
DP 006. Airborne magnetometer survey images, total field and vertical gradient images covering 11D, 11E, 11F, 11G, 11J, 11K, 11N, 20O, 20P, 21A, 21B and 21H, version 1, 1997 (250 m x 250 m resolution).	TIFF	8 Mb	FREE DOWNLOAD
DP 007. Airborne synthetic aperture radar (SAR) images covering 11D, 11E/01, 11E/02, 11E/03 and 11E/04, version 1, 1997, (6 images, 25 m x 25 m resolution).	TIFF	59 Mb, CD-ROM	$10.00
DP 008. Meguma Terrane enhanced second vertical derivative aeromagnetic digital data, version 1, 1997. Includes: (a) images in TIFF format of the aeromagnetic data from OFM's 97-7 to 97-28 and 97-30 to 97-33, without topographic base information or legends; (b) contractor's report on the processing methodology; (CD-ROM product only) (c) plot files in HP-GL/2 format of OFM's 97-7 to 97-28 and 97-30 to 97-33; (CD-ROM product only)	TIFF	573 Mb, CD-ROM 123 Mb, WEB	$10.00
DP 011 Enhanced Aeromagnetic and Digital Elevation Image of Eastern Nova Scotia, Version 1, 2000, M. S. King, (25 m x 25 m, 40 m x 40 m, 80 m x 80 m resolutions)	TIFF JPG PDF	101 Mb/12.9 Mb/ 3.3 Mb, CD-ROM 6.7 Mb/3.4 Mb/ 1.1 Mb 6.9 Mb	$10.00